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Committee D02 on PETROLEUM PRODUCTS AND LUBRICANTS

Originally Issued: February 7, 2013
Corrected: February 21, 2013

Reply to: Richard Grundza
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Unapproved Minutes of the January 24, 2013
Sequence IV Surveillance Panel Meeting held in San Antonio, TX.

A copy of the Agenda is included as Attachment 1

The attendance sheet is included as Attachment 2. Also in attendance via teleconference line were Andy Ritchie and Mike McMillen representing Infineum and Tim Miranda representing Castrol. Membership changes noted during the meeting were to replace Mark Sutherland with Jo Martinez for Oronite and to replace Eric Liu with Fred Gerhart for Southwest Research.

Bill Buscher agreed to be the motion and action item recorder for the meeting.

Minutes from the July 17, 2012 Conference call were approved.

Review of Action Items;
The following is a status of action items from the previous meeting

Motions and Action Items
As Recorded at the Meeting by Pat Lang

1. Action Item – Surveillance panel chair to contact Nissan to inquire about the potential for Nissan to make an additional test kits. Working with Nissan, it appears to there is potential to obtain additional hardware. Chair to meet with Nissan in early February, to be discussed in detail further today.

2. Action Item – SwRI to investigate solution to mild cam batch situation to determine if the mild cams can be brought to an acceptable severity level. Ongoing, to be discussed during today's meeting.

3. Action Item – Surveillance panel chair to solicit suppliers for a GF-5 technology reference oil with ACW performance in the 50 to 90 µm range. One supplier has expressed an interest in possibly supplying an oil, ongoing.

4. Action Item – TMC to reassign RO 1009 assignments that are for the IVA to the VG. Completed.

5. Action Item – Form a task force to further investigate driveline dynamics and the effect on camshaft wear. The task force will be lead by Eric Liu with the following members: Al Lopez, Jerry Brys, Mark Mosher, Rich Grundza, Tim Claudill, Christian Porter and Bill Buscher. On going, report from Eric Liu under item 12.

6. Motion – Remove RO 1009 from the IVA LTMS. Completed.

Fuel Suppliers report. A copy of the Certificate of analysis is included as attachment 3. There were no questions or comments raised for the fuel supplier. It was noted that the IVB test may be run on EEE fuel, depending on how the severity of initial tests performs.

Hardware Issues.

Based on the most recent IVA hardware survey, most labs estimate they will be out of parts by 2014. Activity level has been higher than expected. One lab indicated they ran 99 tests in the 2nd half of 2012 when they had run 53 tests in the first half of 2012. Based on current estimates, it appears that industry will need somewhere between 550 and 600 tests worth of hardware to see testing through 2016. There is potential to obtain another parts solicitation from Nissan, but the hardware is no longer "production" hardware and is now "service" hardware. Bill was unsure what this means and wasn't sure if this hardware will be batched, that is identified with a batch code designation. Bill indicated that gaskets are available and cylinder heads as well. However, heads are bare and will need to have the individual components procured as well and heads will need to be assembled. Over the past few years, the number of runs which a head and block can be run have been increased, and some engines and heads are available which have runs left on them. It was suggested that perhaps some of these heads/blocks can be reinstalled and the remaining runs be used. A suggestion was made that perhaps the number of runs can be increased.

One issue that may cause engines to no longer be used is blowby. Once blowby gets to approximately 16L/min, the ability to maintain fresh air flow is negatively impacted. It was suggested that perhaps the number of runs can be increased to 48 and 24 for blocks and heads, respectively. Oil coolers are also an issue and are no longer available. An adapter can be made to allow the use of the Sequence III cooler, which can be supplied for the foreseeable future. The sequence III cooler is nickel plated, and this cooler can be obtained without plating. ECM's are no longer available, however, there are remanufactured units available from a supplier, Americore Auto.com, the ECM is ECV-RR-SVC. OHT had 4 harnesses in stock, but all have been sold. Labs are to send any failed harnesses to OHT to be evaluated for possible rework.

Discussion next centered around ways to make some "mild" cam batches usable. It was suggested that one way to address some of the severity issues was to potentially regrind cams. Bill Buscher indicated that Southwest had a number of cams reground and the performance of these cams was on target. Considerable discussion ensued regarding the modification of these test parts and the reasoning behind modifying hardware. Bill explained that in screening some of these new camshafts, they noted that there is a 3 – 5 micron convexity on some camshaft batches. When confronted with this, they began to measure each camshaft prior to testing, determining the convexity, then including this pretest value in the total wear value. When confronted with measuring each cam prior to testing, the laboratory sought a way to eliminate the pre-test measurement. The laboratory contacted OHT and asked if they could have the camshafts reground, which is a normal operation for the camshaft supplier. OHT confirmed that these camshafts could be properly refinished. OHT's vendor used to manufacture IIIF/G camshaft, was utilized for regrinding this camshaft and OHT paid them to reverse engineer this material to confirm the profile, surface finish, etc. The profile of the camshaft is unaltered during the refinishing process. OH Technologies, Inc. was unaware of any intended purpose of this material being used in an ASTM method without the knowledge of the Surveillance Panel. Jason Bowden stated OHT told SwRI that it was OHT's position that if this material is going to be used in the ASTM test method the Surveillance Panel should be notified. Approximately 150 tests were determined to be run with reground cams. Several members expressed concerns about the process of regrinding cams and that it was in effect, modifying test hardware, and this activity should not be done without advising the surveillance panel. Bill indicated that batches ~~NK9X230~~ NK04120 and NK05190 had all been reground and used for reference and candidate tests. There was some uncertainty about whether some of batch 087230 cams may have been reworked. Al Lopez raised the question of whether he would have to regrind NK cams in his lab, since Southwest had modified these batches of cams. There was no clear direction on this item in the panel discussions. Bill reiterated the changes the panel had made to the test to deal with severity, which included driveline and mounting issues and standardization of blowby measurements. There were questions about the regrinding process and Jason Bowden explained that the cams are ground to a certain height and the entire lobe and cam is reground. Bill also noted that some of the 99 cams exhibited a surface change relative to other batches. They had attempted plasma cleaning which was able to move the severity of these cams some, but attempts to regrind these did not alter severity. There is no print available for this cam and Bill suggested there may be some 300 cams which may require rework in industry. When asked about potentially allowing this practice, several members commented that the engineering behind this approach appeared to be sound, but the needed more details to make a decision on whether the practice should be acceptable. After more discussions about the regrinding, a motion was made for Southwest to draft a report detailing the cam batches, number of tests and timeline for the measurement changes and the regrinding process. This report is to be included in the minutes from this meeting with a date for completion as the end of business January 31, 2013. This report is included as attachment 4.

Plan to Sustain Test through 2016.

The next series of discussions were centered around what actions need to be taken to make available hardware to meet testing requirements through 2016. There was some discussion about the 990727 cam lot. One lab had identified these cams as mild and another lab had shelved them because of the 1st labs experience. Since this situation was identified, a third laboratory had successfully calibrated on this lot. The first lab intends to run these cams, after appropriate references had been conducted on this hardware.

This lab believes that the severity may not be so much cam related as issues with driveline that were identified much later. Discussions then centered around whether correction factors could be used on mild hardware batches and whether another source of cams could be found. OHT has a supplier who manufactured this cam, but the issue may be the availability of followers to be used with the cams. Al Lopez indicated that followers may be available from abandoned cam lots. Correction factors were not favorably viewed by the panel as they may be lab based and might be quite large, given some of the lot performances in the past. These actions were thought to be unnecessary as it appears Nissan will make available additional hardware. Oil coolers were then addressed. The Nissan Cooler is no longer available. One lab is out of coolers. OHT has an oil cooler that is used for Sequence III tests that can be adapted to the Nissan engine, but it is nickel plated. OHT indicated that these coolers are plated by OHT, so they can be procured without plating. There were some concerns about the copper in these coolers leaching into the oil, but this was primarily a concern in the Sequence III due to much higher oil temperatures. In addition, studies by some suppliers indicated that copper had little or no effect on severity. It was noted that the coolers that are currently used in the IVA are copper brazed and are not nickel plated. The panel approved a motion by Bill Buscher and seconded by Jerry Brys to allow the use of oil cooler, part number OHTKA24-006-1 with adapter OHTKA24-005-1 as an acceptable replacement for the Nissan Cooler, providing an acceptable calibration test has been conducted in the laboratory using this cooler. Once a laboratory switches to this cooler it must continue to use this cooler for subsequent engine installations. This motion was approved by twelve members with one member abstaining. Distributors are currently being refurbished with no issues noted at this time. There are a number of engines and heads that have runs remaining on them based on the current procedure, which could be reinstalled. In previous discussions, it was determined that there is no issue with blowby and oil consumption up to 50 runs on an engine. With that, the panel approved a motion by Al Lopez and seconded by Jerry Brys to increase the number of runs allowed on an engine to 48 and on cylinder heads to 24 runs. This motion was approved by twelve members with one member abstaining. Additional hardware that is no longer available included throttle bodies, exhaust manifolds and intake manifolds. Some labs have been obtaining this hardware from salvage yards. It is believed that throttle bodies can be refurbished and an Action item was assigned to the panel to define a procedure for reworking throttle bodies. Though previously discussed, Jerry Brys was given the action item to provide the source for remanufactured Engine control modules. Labs are also to check their inventory for damaged harnesses that can be shipped to OHT for rework. A copy of Bill's hardware report is included as attachment 5.

Reference Oil Review

Twenty five test targets were reviewed. These data are included in attachment 6. There being almost no difference between the twenty five test and fifteen test means and standard deviations, the panel decided to take no action at this time and to assign an action item to Rich Grundza to fix targets when thirty tests are obtained. Bill Buscher again reiterated the need for an oil in the 50 to 60 micron range and asked panel members to check with their companies and suppliers to see if one could be made available.

Driveline Dynamics Task Force.

Eric Liu presented the work he has done with regard to analyzing driveline vibrations, included as attachment 7. He noted that there is a difference between damped and solid shafts and this difference alters the natural frequency of the driveline. Driveline length can also alter the driveline frequency. Eric intends to attempt to correlate vibration to contact temperature and would like to incorporate data from the other labs. He intends to provide an update for the next meeting.

Test Hardware Modifications

In line with the previous discussions the panel approved a motion by Rich Grundza, seconded by Jason Bowden to not allow modification or alteration of test hardware without the direction of the surveillance panel. This motion was approved unanimously.

Sequence IVB Update

Bill reviewed a presentation from Teri Kowalski of Toyota regarding IVB development. Southwest has two stands installed, one stand operational and the second needing a wiring harness. The engine is a four valve per cylinder, four cylinder engine and currently is using pump fuel. A laser mike will be needed for cam measurement. Bell housings are a special item and need to be procured from Toyota. OHT is developing a jacketed valve cover and also is modifying a front cover to facilitate cam removal and installation. Other labs were asked about their ability to install stands and Afton was unsure whether they would be installing a stand. Lubrizol and Ashland will be installing stands, but probably wouldn't be able to participate in a matrix.

Next meeting.

A conference call or face to face meeting will be undertaken shortly after the minutes are issued with the Southwest report tests regarding the regrinding on convexity of some cam lots.

A copy of the motions and action items from this meeting is included as 8.

With a motion to adjourn from Bill and a second from Rich, the meeting was adjourned at 5:45 PM.

Attachment 1

Sequence IVA Surveillance Panel

San Antonio, TX
Southwest Research Institute, Building 209
January 24, 2013
9:00 a.m. - 5:00 p.m.

A G E N D A

1.	Chairman comments	
2.	Attendance sign-in sheet distribution	
3.	Membership changes	
4.	Motion and Action recorders	
5.	Approval of minutes for 7/12/2012	All
6.	Action item review	Buscher
7.	Fuel supplier report – KA24E Green Fuel • Any issues with supply through 2016?	Carter

8.	Test availability and hardware status
	• Review latest IVA hardware survey results
	• Review severity of remaining camshaft batches
	• Review hardware shortages
	  • Test kits
	  • Oil coolers
	  • Distributors
	  • Wiring harnesses
	  • Other?
	• Review of test unavailability estimates
	• Update on additional industry hardware order from Nissan
		Buscher

9.	Develop plan to sustain test through 2016 • Redistribution of hardware between labs? • Correction factors applied to mild camshaft batches? • OHT to manufacture camshafts if Nissan	All

cannot offer an additional industry hardware order?
  - Reusing rocker arms and rocker shafts with OHT manufactured camshafts?
- Use OHT IIIF/IIIG nickel plated oil cooler as replacement for Nissan oil cooler?
  - An adapter would be necessary (SwRI has already designed one and could make a print available to OHT).
- Use Nissan or aftermarket distributor caps and rotors to rebuild distributors. This is already being done at some labs, with Nissan parts.
- If labs have been saving engine and cylinder head assemblies, the following can be considered:
  - Reinstall earlier engines and cylinder heads that have 12/16/20 and 6/8/10 runs to get the full 32 and 16 runs that are now allowed. This is already being done at some labs.
  - Rebuild used engine and cylinder head assemblies to allow for an additional 32 and 16 runs?
  - Increase the number of allowed runs beyond 32 and 16 runs?
- Acquire studs for cam caps and rocker covers to eliminate problems with threads in the aluminum cylinder heads?
- Use aftermarket gaskets and seals if Nissan components are no longer available?
- Acquire used components from salvage yards to replace worn components from test stand kits. This is already being done at some labs.
  - Need to locate components from 1994 – 1996 Nissan pickup trucks.
  - Refurbish some components, such as throttle bodies, if necessary.
- Repair damaged and currently unusable wiring harnesses?

10. Reference Oil Review — Grundza/Buscher

- RO 1006-2 target status

- New RO status

11.	Update on driveline dynamics task force	Liu
12.	Update on Sequence IVB test development	Kowalski/ Buscher
13.	Review Scope & Objectives	Buscher
14.	Old business	
15.	New business	
16.	Next meeting	
17.	Tour of Sequence IVB test stands	All
18.	Adjourn	

Attachment 2

MEMBERSHIP
ASTM IVA SURVEILLANCE PANEL

January 24, 2013

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	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	
	Phone No.: Fax No.: Email:	

PRODUCT:	**KA24E TEST FUEL**		**Batch No.:**
HALTERMANN			**TMO No.:**
PRODUCT CODE:	**HF0008**		**Tank No.:**
			Date:

TEST		METHOD	UNITS	SPECIFICATIONS		
				MIN	TARGET	MAX
Distillation - IBP		ASTM D86	°F	75		95
	5%		°F			
	10%		°F	120		135
	20%		°F			
	30%		°F			
	40%		°F			
	50%		°F	200		230
	60%		°F			
	70%		°F			
	80%		°F			
	90%		°F	300		325
	95%		°F			
Distillation - EP			°F	385		415
Recovery			vol %		Report	
Residue			vol %		Report	
Loss			vol %		Report	
Gravity		ASTM D4052	°API	58.7		61.2
Density		ASTM D4052	kg/l	0.734		0.744
Reid Vapor Pressure		ASTM D5191	psi	8.8		9.2
Carbon		ASTM E191	wt fraction	0.858		0.8667
Carbon		ASTM D3343	wt fraction		Report	
Sulfur		ASTM D2622	wt %	0.01		0.04
Lead		ASTM D3237	g/gal			0.05
Oxygen		ASTM D4815	wt %			0.2
Composition, aromatics		ASTM D1319	vol %			35
Composition, olefins		ASTM D1319	vol %	5		10
Composition, saturates		ASTM D1319	vol %		Report	
Oxidation Stability		ASTM D525	minutes	1440		
Copper Corrosion		ASTM D130				1
Gum content, washed		ASTM D381	mg/100ml			5
Research Octane Number		ASTM D2699		96		97.5
Motor Octane Number		ASTM D2700			Report	
R+M/2		D2699/2700			Report	
Sensitivity		D2699/2700		7.5		
Net Heat of Combustion		ASTM D240	btu/lb		Report	
Color		Visual			Green	

Attachment 3

AL1221GP03	**AJ1521GP01**	**AF2621GP02**	**AE1521GP01**	**AB0921GP05**
802120	**802000**	**801912**	**801852**	**903591**
52	**235**	**235**	**234**	**662**
1/3/2013	**10/18/2012**	**6/26/2012**	**5/22/2012**	**2/17/2012**
RESULTS	**RESULTS**	**RESULTS**	**RESULTS**	**RESULTS**
91	**91**	**86**	**86**	**90**
114	**113**	**111**	**111**	**114**
126	**127**	**126**	**125**	**125**
145	**147**	**148**	**146**	**144**
170	**172**	**173**	**170**	**168**
200	**202**	**202**	**200**	**199**
220	**221**	**221**	**220**	**220**
230	**229**	**232**	**231**	**230**
239	**239**	**241**	**240**	**239**
255	**256**	**258**	**257**	**257**
316	**315**	**320**	**315**	**318**
344	**343**	**348**	**343**	**344**
394	**397**	**404**	**387**	**394**
97.5	**97.2**	**96.9**	**97.8**	**97.8**
1	**0.9**	**1.1**	**1.1**	**1.2**
1.5	**1.9**	**2**	**1.1**	**1**
59.9	**59.9**	**59.4**	**60**	**59.7**
0.738	**0.738**	**0.741**	**0.738**	**0.739**
9	**9.2**	**9**	**9.2**	**9.1**
0.8622	**0.8639**	**0.8626**	**0.8632**	**0.8627**
0.8646	**0.8643**	**0.8645**	**0.8644**	**0.865**
0.01	**0.02**	**0.02**	**0.02**	**0.02**
None Detected	**None Detected**	**None Detected**	**None Detected**	**None Detected**
None Detected	**None Detected**	**None Detected**	**None Detected**	**None Detected**
28.4	**27.8**	**27.8**	**27.9**	**28.8**
6	**5.8**	**5.9**	**5.7**	**6.2**
65.6	**66.3**	**66.3**	**66.4**	**65**
1440+	**1440+**	**1440+**	**1440+**	**1440+**
1a	**1a**	**1a**	**1a**	**1a**
<0.5	**<0.5**	**2**	**<0.5**	**<0.5**
97.3	**97.3**	**97.2**	**97.3**	**97.2**
88.2	**87.8**	**88.1**	**88.2**	**88.2**
92.8	**92.6**	**92.6**	**92.8**	**92.7**
9.1	**9.5**	**9.1**	**9.1**	**9**
18308	**18322**	**18366**	**18370**	**18344**
Green	**Green**	**Green**	**Green**	**Green**

Attachment 4

Report On the Discovery of Convex Camshaft Lobes in the Sequence IVA Test and the Development and Implementation of Corrective Actions

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Introduction

On January 24, 2013 the Sequence IVA Surveillance Panel conducted a face-to-face meeting. The primary purpose of this meeting was to discuss hardware availability and action to sustain this test through 2016. While discussing hardware currently available in the industry and plans for an additional hardware order with Nissan, SwRI informed the Surveillance Panel that starting with the 080730 lot it had identified multiple camshaft lots with a manufacturing anomaly on the lobe surface that prevented accurate wear measurements and produced unacceptable mild reference test results of three to four standard deviations from target. SwRI further informed the Surveillance Panel that regrinding the lobes of the camshafts from these lots was found to be a solution to correct the manufacturing anomaly while providing proper severity for the Sequence IVA test.

SwRI also stated that it had taken action and reground all camshafts from five lots, once the anomaly was identified and regrinding was proven effective. SwRI conducted "in-house" tests to prove out the performance of the reground camshafts, conducted successful calibration tests to introduce the reground camshafts and conducted candidate tests with the reground camshafts following the successful reference tests on reground camshafts. This information resulted in concern from some of the panel members, including the Test Monitoring Center. A motion was made at the Surveillance Panel meeting for SwRI to issue this report to the panel members for review. It is important to note that at the time of the discovery of this anomaly, all hardware orders from Nissan had been placed for the life of the Sequence IVA test, and the option to reject the quantities of hardware that SwRI determined to be unusable in its "as received" state would have resulted in the Sequence IVA test becoming unavailable within the industry prior to its expected life through GF-5 of 2016.

Description of the Anomaly

The manufacturing anomaly that SwRI identified is described as convexity on the camshaft lobe surface. This surface is supposed to be flat. The convex lobes exhibit a crown that protrudes up to 7µm above the flat surface that normally is used as the baseline to calculate the wear value. A convex camshaft lobe that is undetected and/or uncorrected would lead to an incorrect wear measurement that is milder than the actual wear on a camshaft lobe, because the crown material that is worn off above the baseline is not accounted for when the standard Sequence IVA camshaft wear measurement method is applied. A visual example is shown in Figure 1.

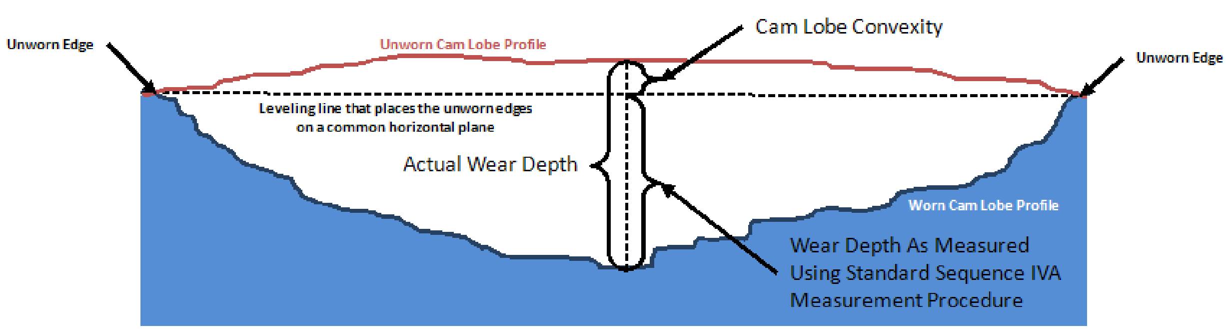
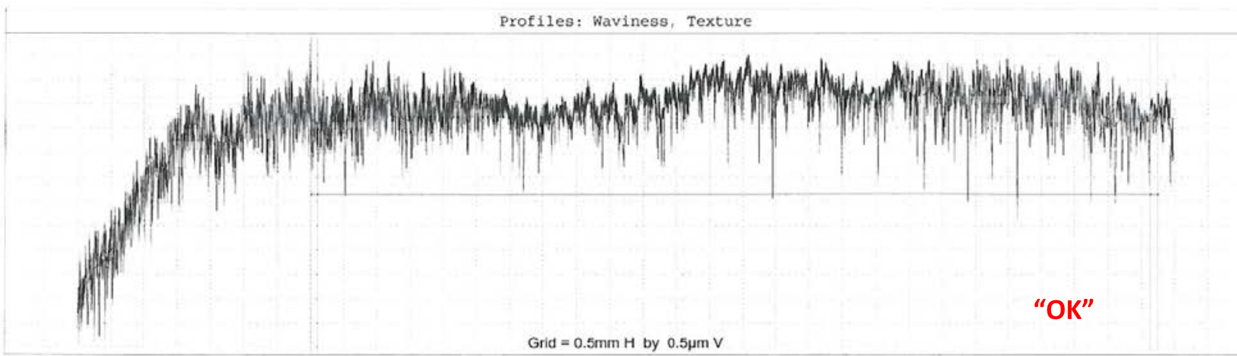
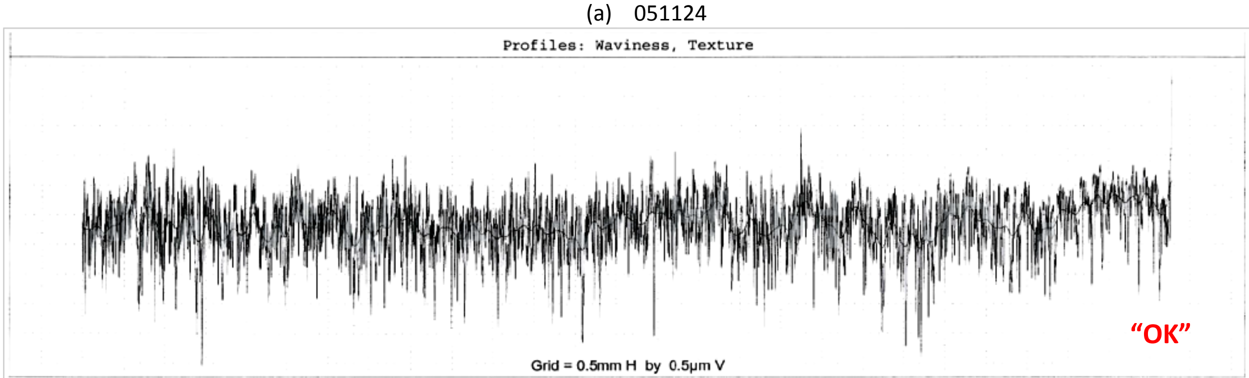


Figure 1: Explanation of Anomaly

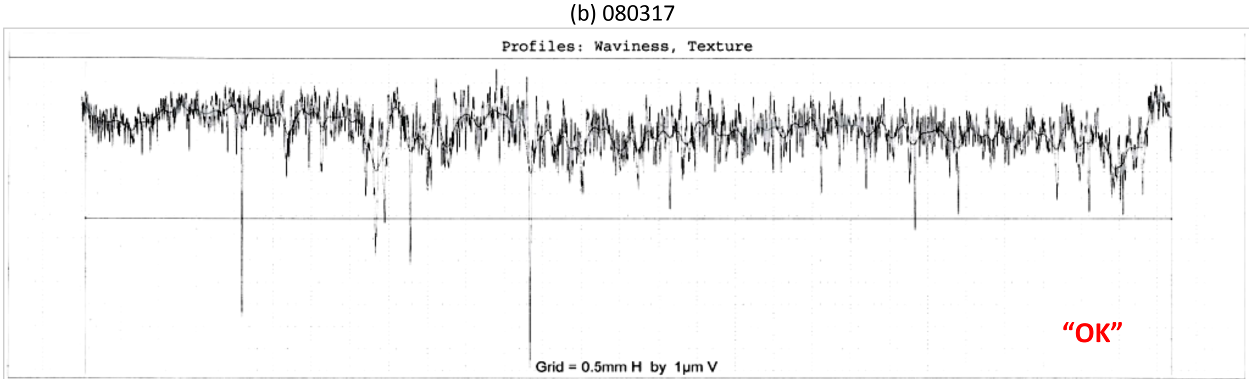
Starting with camshaft lot 080730, the camshaft lobe surfaces, on intermittent camshafts from some lots and on all camshafts from other lots, were found with this condition. For these camshafts, the lobe surface was found to be a convex curve, whose peak was above the horizontal line that connected the two edges of the camshaft lobe. Figure 2 shows the pre-test lobe measurements over time for the various camshaft batches received by SwRI for testing. As shown in Figure 2, this anomaly was not observed on any camshaft lobe surfaces prior to the 080730 lot. This was first discovered while taking traces of the base circle profile in the case where a post-test lobe is missing a discrete non-worn edge (as per the no-form method in Section 11.5.3.6 of the Sequence IVA Test Method ASTM D 6891). It was also noted that camshaft lobe surfaces from lots manufactured in 2008 and later were progressively non-linear, and the peak of the curve progressively increased, as shown in Figure 2.



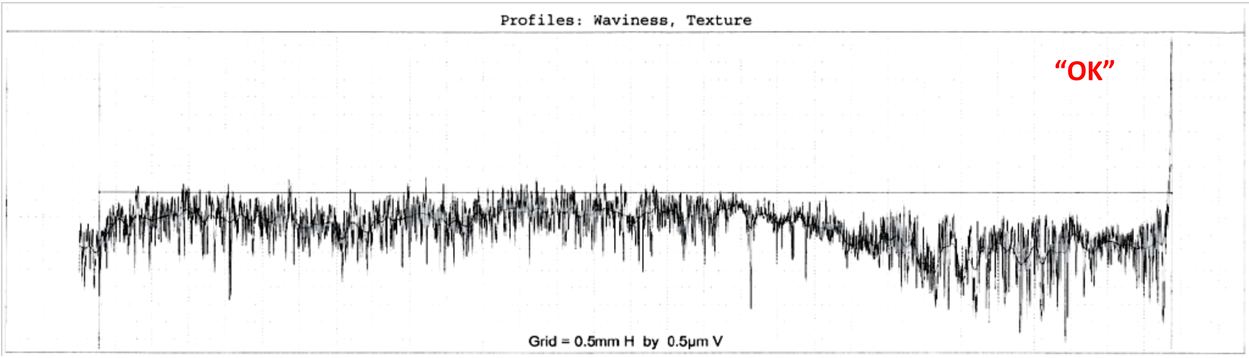
(a) 051124



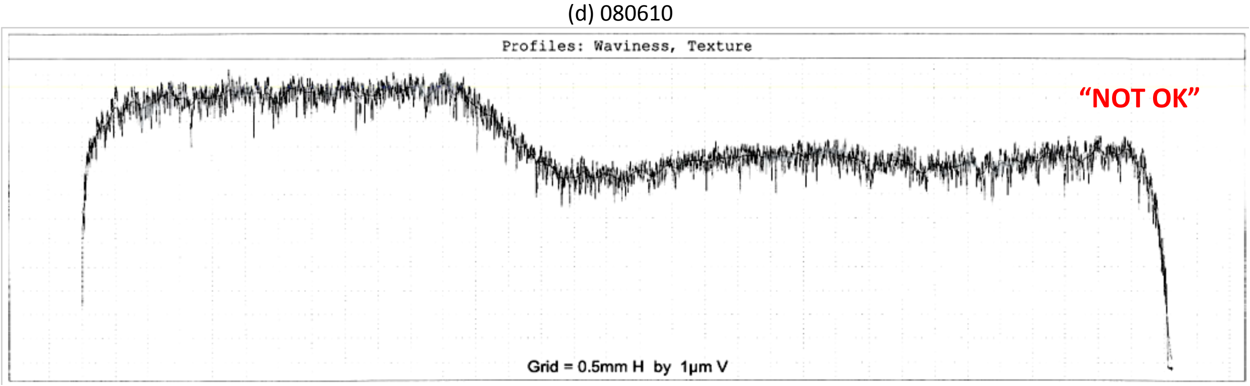
(b) 080317



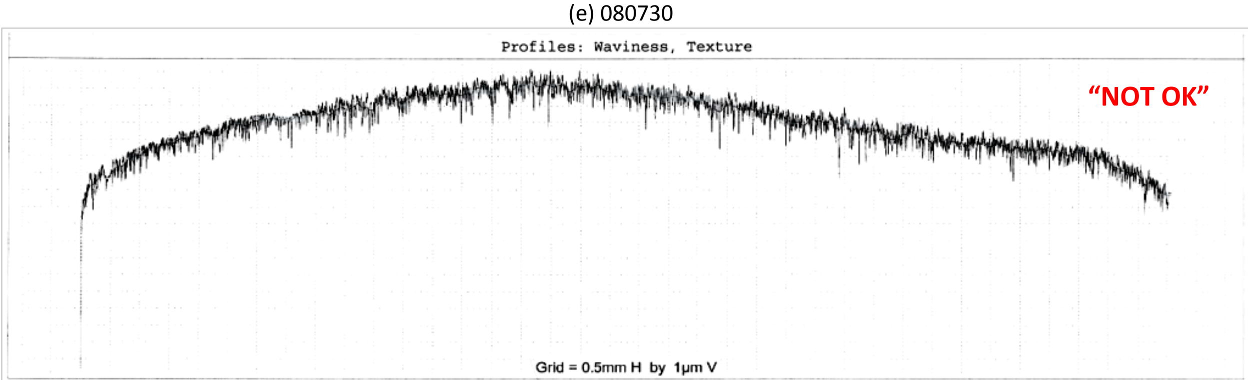
(c) 080418



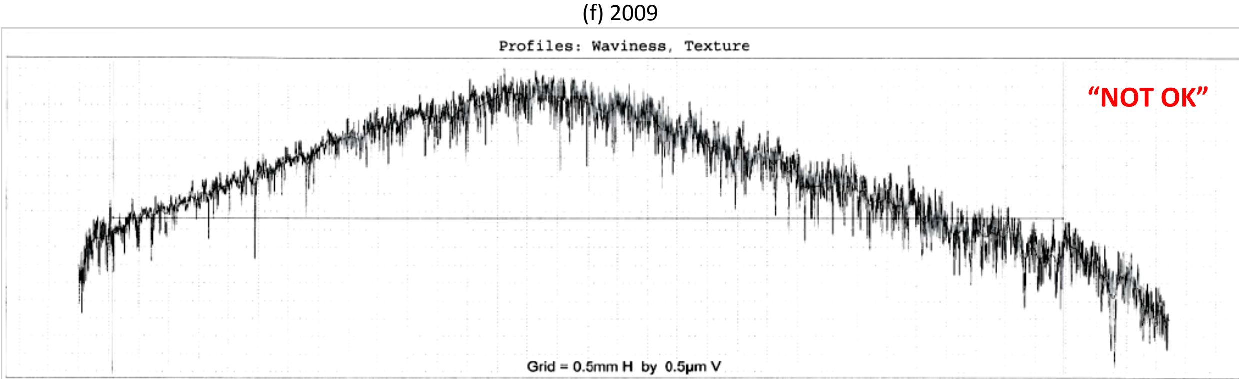
(d) 080610



(e) 080730



(f) 2009



(g) NK9X230

Figure 2: Progression of Camshaft Lobe Surface Curvature Over Seven Camshaft Lots; (a) 051124, (b) 080317, (c) 080418, (d) 080610, (e) 080730, (f) 2009, (g) NK9X230

The waviness (Wt) of the cam lobe surfaces of multiple camshaft lots are shown in Figure 3. For the purposes of this discussion, Wt is described as the maximum difference between any two points on a surface profile trace of a camshaft lobe. Therefore, Wt represents the distance from the peak of the curve to the edges. As the Wt value increases so does the convexity of a new camshaft lobe surface profile.

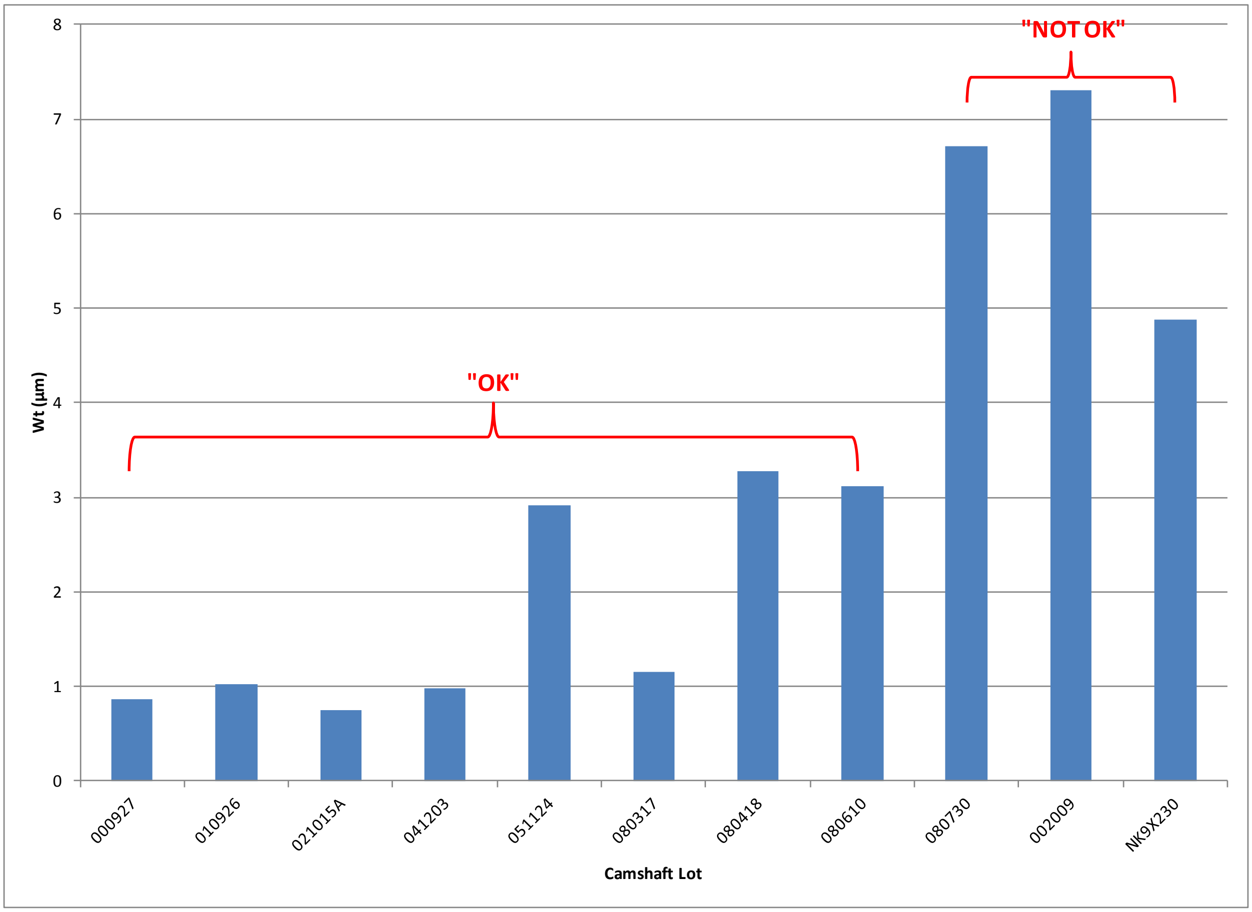


Figure 3: Wt of Camshaft Lobe Surfaces from Multiple Camshaft Lots

The curvature of the camshaft lobe surface ultimately affected the wear depth measurement conducted at each position of the camshaft lobe (7 per lobe, 84 per camshaft). The standard wear measurement method, described in Section 11.5.3.3 of ASTM D 6891, states that the unworn edges found on each camshaft lobe are to be used "to define a two-point reference line" from which to measure the maximum depth of wear. A diagram describing the standard measurement method for determining the maximum wear depth is shown in Figure 4.

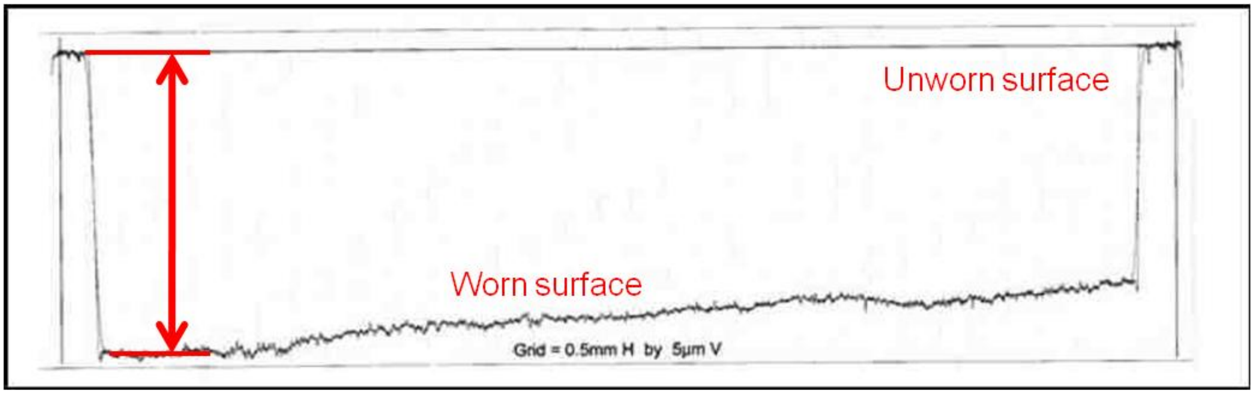


Figure 4: Standard Procedural Measurement of the Maximum Wear Depth Seen at a Camshaft Lobe Position

The maximum wear depth, by definition, is the greatest distance between the unworn surface and the worn surface of the camshaft lobe. Therefore, the accuracy of the measurement method described in the test procedure was based on the assumption that the original surface of the camshaft lobe could be properly represented by a flat line that connected the two unworn surfaces at the edge of each camshaft lobe; the assumption being that the original camshaft lobe surface was flat, not curved.

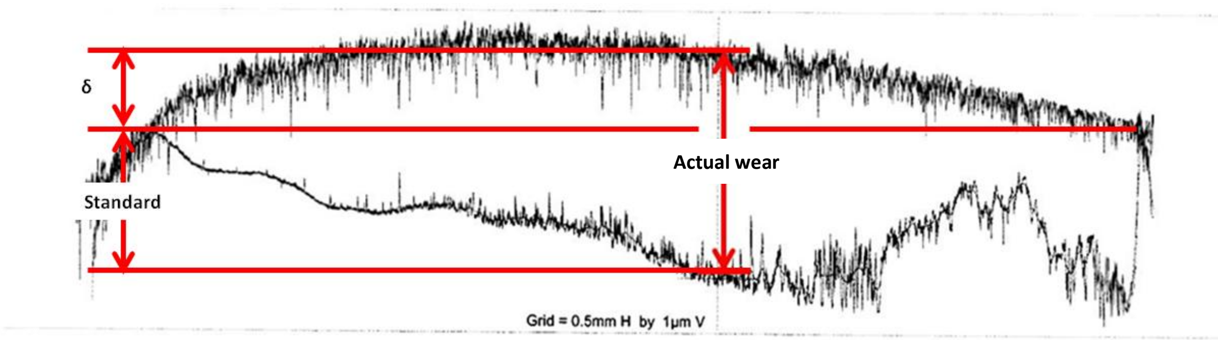
The convex curvature of the camshaft lobe surface undermines the assumption of an originally flat camshaft lobe profile; the pre-test profile of the camshaft lobe could no longer be defined with just two points defined by unworn edges. The integrity of the measurement of maximum wear depth had been jeopardized due to insufficient definition of the original camshaft lobe profile.

It is important to note that not a single camshaft, from any of these lots, measured greater than or equal to the camshaft rejection criteria indicated in Section 9.6.2.3 of ASTM D 6891 (*reject any camshaft that exhibits taper, concavity, or convexity of more than the 10µm variation*). However, if left uncorrected or not measured properly post test, it is SwRI's opinion that the cumulative summation of the error has potential to skew results, thus allowing a borderline failing oil to become a passing oil.

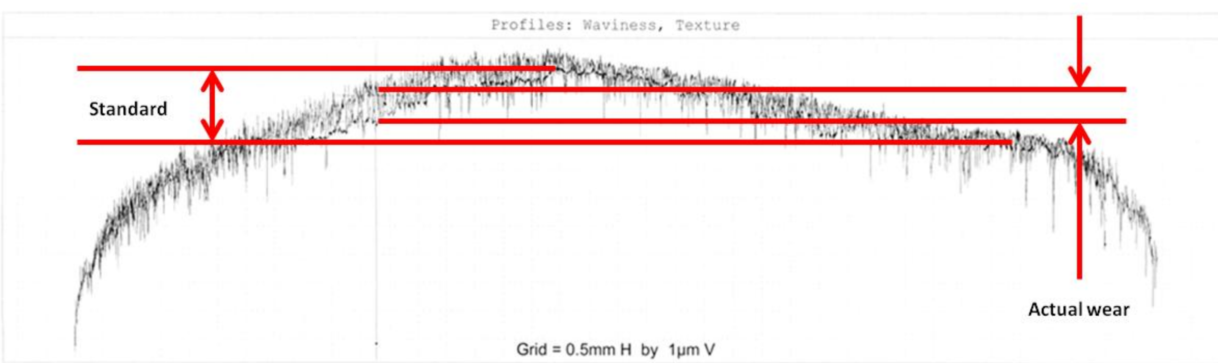
Development of the Pre-Test/Post-Test Overlay Wear Measurement Method

Upon discovery of this anomaly at SwRI, the initial engineering decision was to utilize the pre-test camshaft lobe profile trace to define the reference line for measuring the maximum wear depth. SwRI followed the guidelines indicated in Section 11.5.3.12 of ASTM D 6891. Section 11.5.3.12 states *"It will rarely occur that the above techniques provide a wear measurement that appears unreasonable (for example, a known unworn area that is not displayed as the highest point on a trace). When this occurs, consult the test engineer for the proper leveling and wear interpretation of that trace. Document the process utilized to make this wear measurement evaluation in the test report."* Also, Section 11.5.3.4 of ASTM D 6891 references use of the pre-test profile to extrapolate the reference line.

While conducting post-test camshaft lobe measurements, the pre-test camshaft lobe profile was overlaid with the post-test camshaft lobe profile as illustrated in Figure 5. The maximum wear depth was determined by taking the largest difference between the pre- and post-test camshaft lobe profiles. This is indicated by "Actual Wear" in Figure 5. In all instances where this wear measurement method was used to determine test results, comments were added to all the final test reports, reflecting that action.



(a) Moderate Wear



(b) Low Wear

Figure 5: Comparison of Overlay Method and Standard Sequence IVA Method for Measurement of Camshaft Lobe Wear; (a) Moderate Wear, (b) Low Wear

It is shown in Figure 5 that by overlaying the pre- and post-test camshaft lobe profiles, the average camshaft wear (ACW) was higher than the ACW obtained using the standard measurement method. Figure 5b illustrates that, in actuality, if only the standard Sequence IVA ACW measurement method is applied, the convexity of the cam lobe is measured in the case of a low wear cam lobe instead of the actual wear depth.

An example of a post-test camshaft measured by both ACW measurement methods is shown in Figure 6. The conventional method produces an average wear of 71.23µm and the overlay method produces an average wear of 80.89µm. The discrepancy between the average camshaft wear values obtained from each measurement method is 13.6% for this example, and has the potential to be even greater depending on the height of the convexity and the severity of the wear.

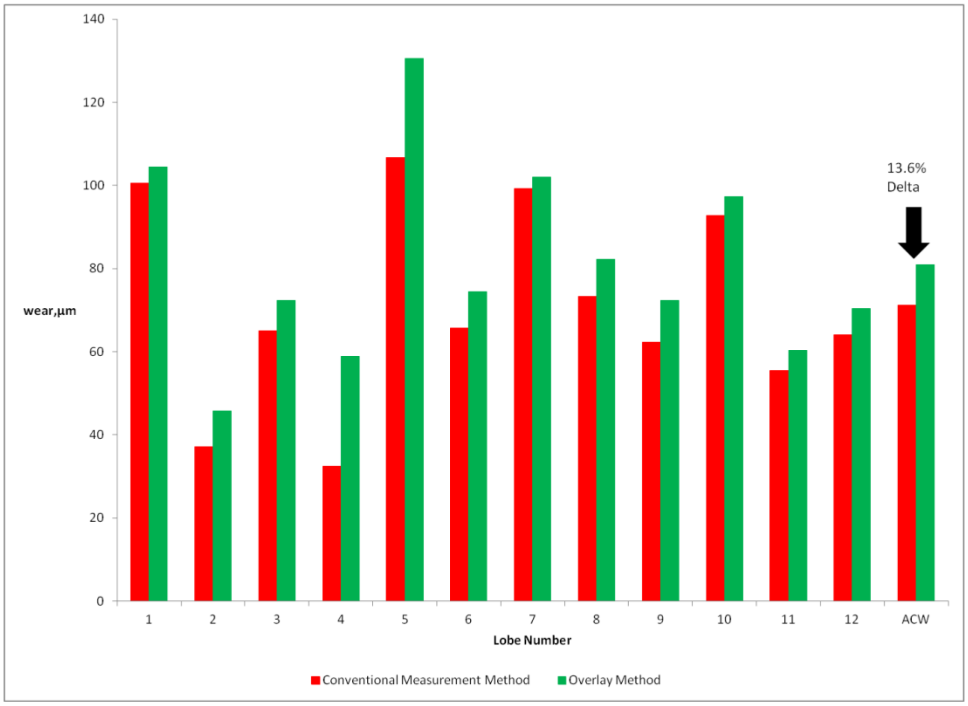


Figure 6: Comparison of ACW Result Using Overlay Method and Standard Sequence IVA Method for Measurement of Camshaft Lobe Wear[1]

The pre-test/post-test overlay wear measurement method was proven as an effective way to address camshafts with the convex lobe anomaly, but it had some drawbacks that led SwRI to consider additional solutions to the problem. The primary drawbacks include a certain amount of human subjectivity when overlaying the pre-test and post-test camshaft lobe profiles, and the difficulty applying this method to a post-test lobe with the absence of a discrete non-worn edge.

[1] The detailed results tables for the two measurement methods are included in Appendix A Table 1.

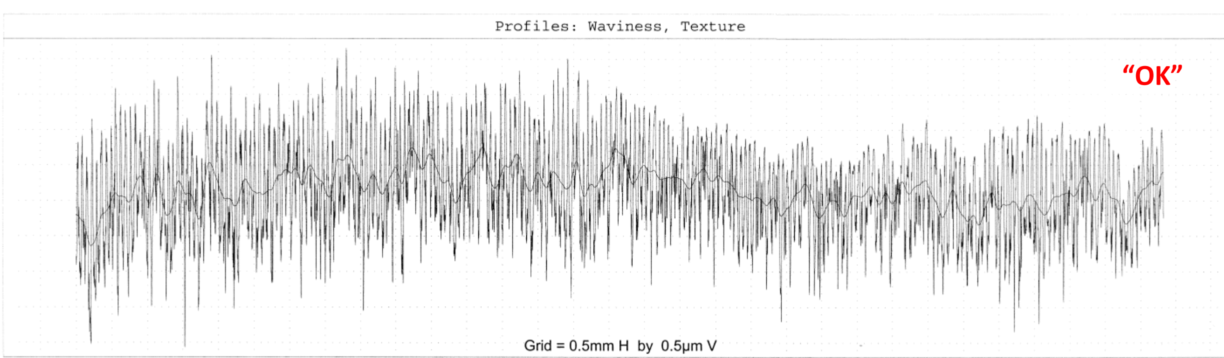
Restoration of the Flat Camshaft Lobe Profile

An alternative to conducting the measurement with overlaying profile traces was to restore the profile of the original camshaft lobe surface to be flat. Thus, the surface of the camshaft lobe was reground to produce a flat surface profile as well as target the average roughness of the camshaft lobe surfaces of camshafts manufactured prior to 2008. The average roughness (Ra), skew (Rsk), and Wt of the base circle traces of previous camshaft lots were used as a reference to restore the surface of the camshaft lobes. A table of the Ra, Rsk, and Wt is shown in Table 1.

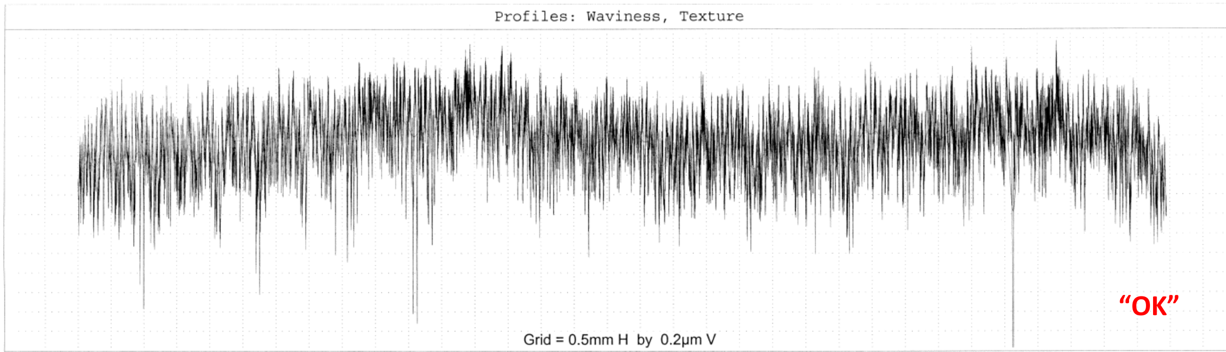
Cam Batch	Ra (µm)	Rsk	Wt (µm)
990628	0.25	-1.42	0.77
990628	0.29	-0.93	1.42
000927	0.35	-0.84	0.87
000927	0.32	-0.74	0.97
010926	0.42	-0.46	1.40
010926	0.22	-1.22	1.03
010926	0.31	-0.74	1.23
010926	0.32	-0.91	1.10
021015A	0.20	-0.62	0.75
041203	0.21	-0.40	1.02
041203	0.19	-0.61	0.98
051124	0.28	-0.89	2.91
Average	**0.28**	**-0.82**	**1.20**
St. Dev.	**0.07**	**0.29**	**0.58**

Table 1: Ra, Rsk, and Wt of Camshaft Lobe Surfaces Prior to 2008

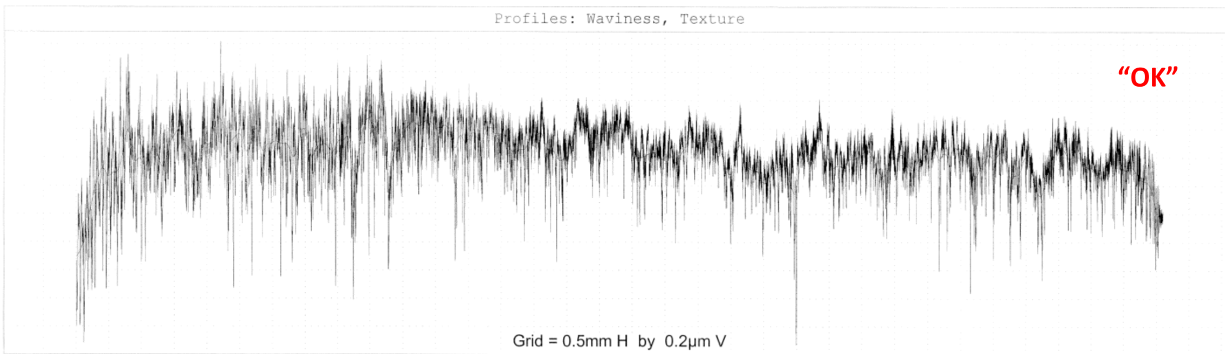
For comparison, the reground camshaft lobes had an average Ra, Rsk, and Wt of 0.26µm, -0.14, and 0.79µm, respectively. An example of the final reground camshaft lobe surface from each of the reground camshaft lots are shown in Figure 7.



(a) 080730 After Regrinding



(b) NK04120 After Regrinding



(c) NK05190 After Regrinding

Figure 7: Camshaft Lobe Surfaces of Reground Camshafts, Including Three Camshaft Lots;(a) 080730, (b) NK04120, (c) NK05190[2]

This regrinding procedure was pursued after SwRI discussed the manufacturing anomaly with a performance camshaft manufacturer. This camshaft manufacturer was familiar with the anomaly, usually resulting from tool wear during a production run of camshafts, and indicated it was common to regrind camshafts if this anomaly was identified at the completion of the machining process. After discussions with this camshaft manufacturer, SwRI contacted OHT and inquired about the possibility of having OHT regrind a couple of example camshafts from lot 080730. SwRI choose to use OHT for the regrinding, because of their historical expertise in this specific area.

[2] Please note that the surface profiles and Wt data generated on un-ground camshafts from lots NK04120 or NK05190, to determine the need for regrinding was not saved, and therefore was unavailable for inclusion in the "Description of the Anomaly" section of this report

The details of the OHT regrinding process for all Sequence IVA camshafts reground to-date are included below:

- Regrinding performed by supplier that manufactures Sequence IIIF and IIIG camshafts for OHT.
- Material removal is limited to 5µm off of the lobe surface during the regrinding process.
- Production lobe profile maintained.
- Profile of reground camshafts must be comparable to an acceptable test camshaft example supplied by SwRI.
- Cam lobes must be reground to Ra, Rsk, and Wt specifications supplied by SwRI.
- 100% inspection of final product.
- Post-grinding profile traces must be conducted at supplier on a random sampling of final product.

Prior to running any official Sequence IVA reference and candidate tests, “in-house” testing, using reference oil retains, was conducted to prove comparability of the test results. After successful in-house testing, reference tests were conducted. Following successful reference tests, candidate tests were conducted.

Timeline

December 2009: The lobe surfaces of camshafts from lot 080730 were found to be convex. An alternative measurement method (pre-test/post-test overlays) was developed. This measurement method was implemented on all reference and candidate tests that were conducted on convex lobe camshafts, and documented in all test reports that used this measurement method. This occurred from December 2009 through May 2010. SwRI contacted a camshaft manufacturer and learned of the regrinding process. SwRI also contacted OHT and solicited regrinding services from OHT and their camshaft manufacturing supplier. Two camshafts from lot 080730 were sent to OHT for regrinding.

January 2010: Average Ra, Rsk, and Wt values were calculated from pre-2008 camshaft lots and were provided to OHT as surface finish specifications. A new, acceptable test camshaft was provided to OHT for the lobe profile to be reverse engineered from. The lobe surfaces of <u>some</u> camshafts from lot 2009 were found to be convex. The alternative measurement method (pre-test/post-test overlays) was implemented on all reference and candidate tests that were conducted on convex lobe camshafts from lot 2009, and documented in all test reports that used this measurement method. This occurred from January 2010 through February 2011. SwRI did not regrind any camshafts from lot 2009, since there was a mix of flat and convex lobe camshafts and SwRI wanted to first prove out the camshaft lobe regrinding with lot 080730.

February 2010: Two reground camshafts from lot 080730 were returned to SwRI. The camshaft lobe surfaces were inspected and were found to be flat and within the indicated surface finish specifications. SwRI conducted an “in-house” test on RO 1007 retains to prove equivalence in the performance of the reground camshafts. ACW was measured to be 94.53µm. This was a passing RO 1007 result, 0.634 standard deviations severe of the 84.76µm target.

March 2010: 39 camshafts from lot 080730 were sent to OHT for regrinding.

May 2010: 38 camshafts from lot 080730 were successfully reground and returned to SwRI.

June 2010: Initially, three reference tests were conducted consecutively on the reground camshafts from lot 080730 on Stand 78A (tests no. 78A-0-323, 323A, and 323B). The first two tests were on RO 1007 and the third test was on RO 1009. The ACW results were 109.22µm, 113.34µm, and 16.83µm. A total of six reference tests were conducted on Stand 78A with reground camshafts from lot 080730; only 78A-0-339 failed severe on RO 1007 (ACW = 122.30µm). All remaining reground camshafts from lot 080730 were used to conduct candidate tests during these reference periods. This occurred from June 2010 through October 2011.

NOTE: For RO 1007, mean = 84.76µm and standard deviation = 15.40µm
For RO 1009, mean = 18.76µm and standard deviation = 7.05µm

January 2011: The lobe surfaces of <u>some</u> camshafts from lot NK9X230 were found to be convex. The alternative measurement method (pre-test/post-test overlays) was implemented on all reference and candidate tests that were conducted on convex lobe camshafts from lot NK9X230, and documented in all test reports that used this measurement method. This occurred from January 2011 through April 2012. SwRI did not regrind any camshafts from lot NK9X230, since there was a mix of flat and convex lobe camshafts.

October 2011: 230 camshafts, 185 from lot NK04120 and 45 from lot NK05190, were sent to OHT for regrinding. They were to be reground and returned to SwRI in two separate groups.

January 2012: 95 reground camshafts, 85 from lot NK04120 and 10 from lot NK05190, were returned to SwRI. Reference test 54-0-316 was conducted on a reground camshaft from lot NK04120 and on RO 1007, yielding an ACW result of 32.94µm (fail). The failing mild result was determined to be related to the test stand's driveline, not the reground camshaft, and the test was invalidated.

February 2012: Reference test 78A-0-377 was conducted on a reground camshaft from lot NK04120 and on RO 1007, yielding an ACW result of 52.53µm (fail). Reference test 78A-0-377A was conducted on a reground camshaft from lot NK04120 and on RO 1006-2, yielding an ACW result of 85.48µm (pass). A total of twelve reference tests were conducted on Stands 54, 78A and 79A with reground camshafts from lot NK04120. All remaining reground camshafts from lot NK04120 were used to conduct candidate tests during these reference periods. This occurred from February 2012 through January 2013. A few reground camshafts from lot NK04120 currently remain in SwRI's inventory.

NOTE: For RO 1006-2, mean = 100.18µm and standard deviation = 18.65µm

May 2012: 135 reground camshafts, 100 from lot NK04120 and 35 from lot NK05190 were returned to SwRI.

December 2012: Reference test 79A-0-500A was conducted on a reground camshaft from lot NK05190 and on RO 1006-2, yielding an ACW result of 82.28µm (pass). Reference test 78A-0-420 was conducted on a reground camshaft from lot NK05190 and on RO 1006-2, yielding an ACW result of 88.02µm (pass). Three candidate tests have been conducted on reground camshaft from lot NK05190 to-date.

NOTE: For RO 1006-2, mean = 103.39µm and standard deviation = 13.68µm

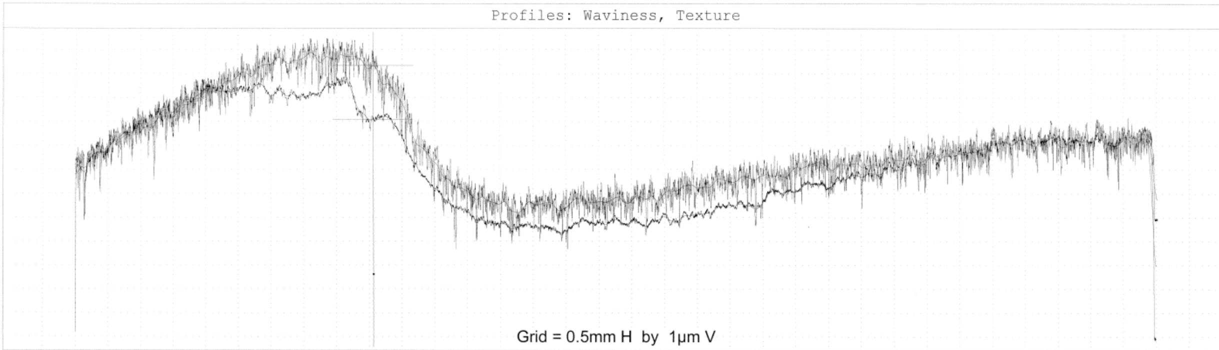
Number of Tests Conducted with Pre-Test/Post-Test Overlay Wear Measurement Method

The number of reference and candidate oil tests conducted using the convex lobe surface camshafts (non-reground) and pre-test/post-test overlay wear measurements are shown in Table 2. These tests include camshafts from three camshaft lots; 080730, 2009 and NK9X230.

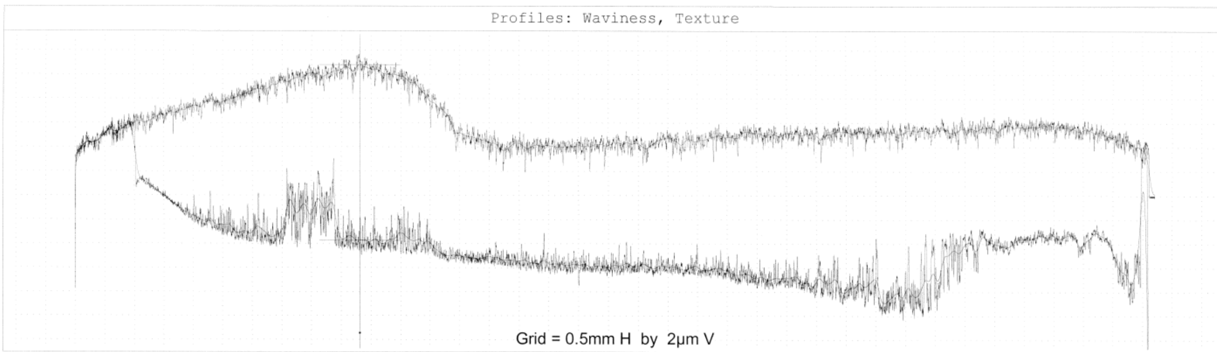
Total Reference Oil Tests:	22
Chartable Reference Tests:	13
Acceptable Reference Tests:	12
Non-Acceptable Reference Tests:	1
Successful Reference Periods	11
Total Candidate Oil Tests:	133
ACC-Registered Tests:	58
Passing	30
Failing	28
Invalid	0

Table 2: Reference and Candidate Oil Tests Run Using Convex Lobe Surface Camshafts and Pre-Test/Post-Test Overlay Wear Measurements

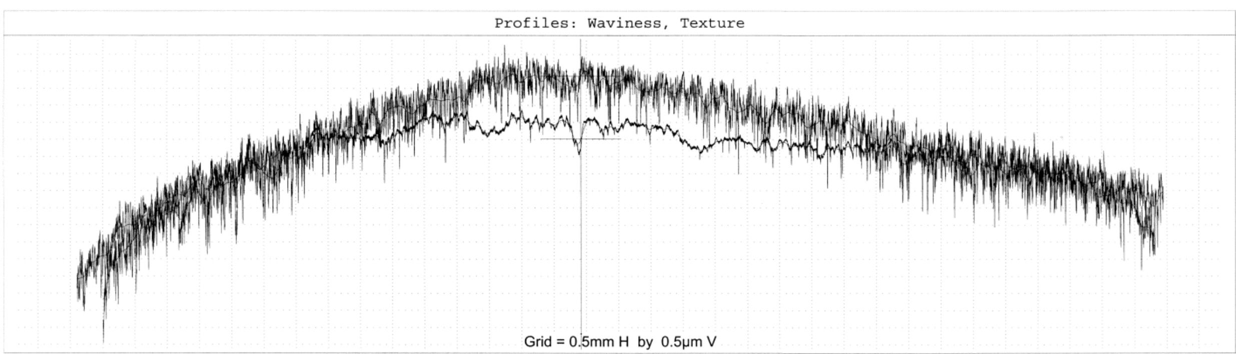
Examples of pre-test and post-test profile trace overlays for all three camshaft lots, 080730, 2009 and NK9X230, are shown in Figure 8. Low wear and high wear examples are included for each camshaft lot. The necessity for this measurement method is extremely evident in the low wear examples, and without it, a lab would measure the convexity instead of wear from the baseline.



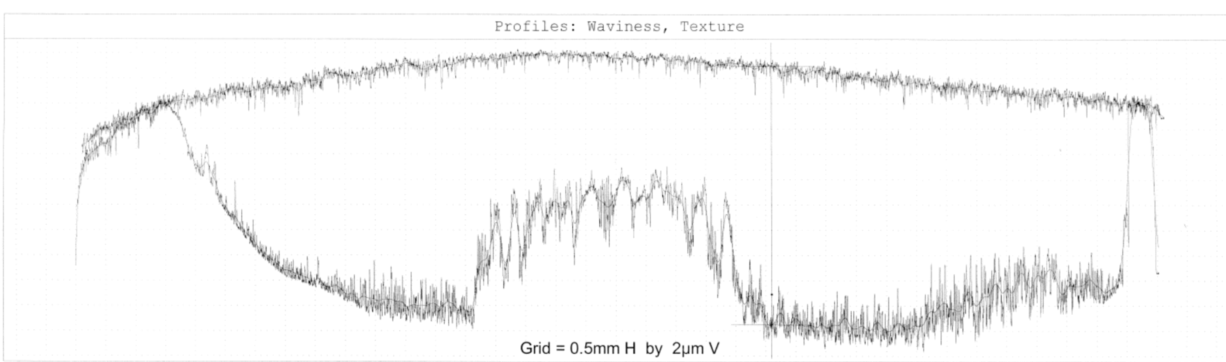
(a) 080730 Low Wear



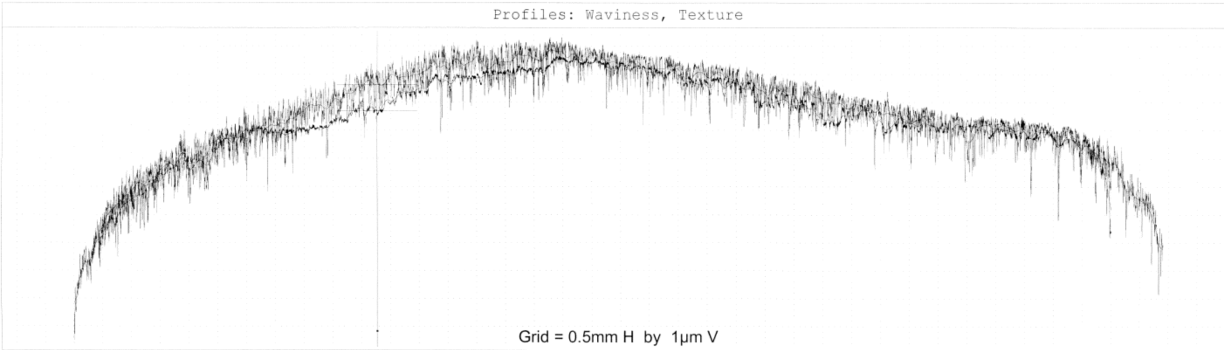
(b) 080730 High Wear



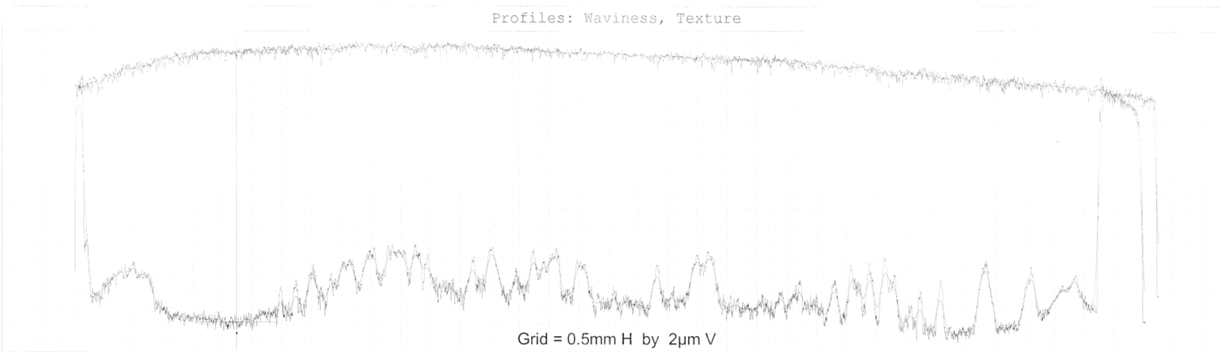
(c) 2009 Low Wear



(d) 2009 High Wear



(e) NK9X230 Low Wear



(f) NK9X230 High Wear

Figure 8: Examples of Low and High Wear Using Pre-Test and Post-Test Profile Trace Overlays for Camshaft Lots 080730 (a) & (b), 2009 (c) & (d), NK9X230 (e) & (f)

Number of Tests Conducted with Reground Camshafts

The number of reference and candidate oil tests conducted using the reground camshafts are shown in Table 3. These tests include camshafts from three camshaft batches; 080730, NK04120 and NK05190.

Total Reference Oil Tests:	33
Chartable Reference Tests:	18
Acceptable Reference Tests:	16
Non-Acceptable Reference Tests:	2
Successful Reference Periods	15
Total Candidate Oil Tests:	167
ACC-Registered Tests:	103
Passing	70
Failing	32
Invalid	1

Table 3: Reference and Candidate Oil Tests Run Using Reground Camshafts

Reground versus Non-reground ACC-Registered Candidate Data

SwRI candidate data was reviewed in a time period from December 2009 to January 24, 2013. The total number of ACC-registered candidate tests conducted during this period is shown in Table 4. These tests include camshafts from five camshaft batches; 080730, 2009, NK9X230, NK04120 and NK05190.

	Reground	**Non-reground**
ACC-Registered Tests:	103	129
Passing	70	99
Failing	32	30
Invalid	1	0

Table 4: Reground and Non-Reground ACC-Registered Candidate Oil Tests Run

The calculated pass percentages for this data set are as follows:

- Non-reground = 99/129 = 77%
- Reground = 70/102 = 69%
- All = 169/231 = 73%

Severity Comparison

SwRI conducted this severity comparison using reference oil test results from all chartable SwRI reference tests, starting in October 1999. This includes 127 tests, a well represented mix of camshafts with no lobe anomalies, camshafts with convex lobe surfaces that were not reground, but had pre-test/post-test overlay wear measurements, and reground camshafts.

The plot of ACW Y_i and ACW Z_i from reference test results vs. completion date is shown in Figure 9. Any test conducted with a reground camshaft is indicated with a circle around the square. This data indicates that the introduction of the reground camshafts did not shift the severity of the test.

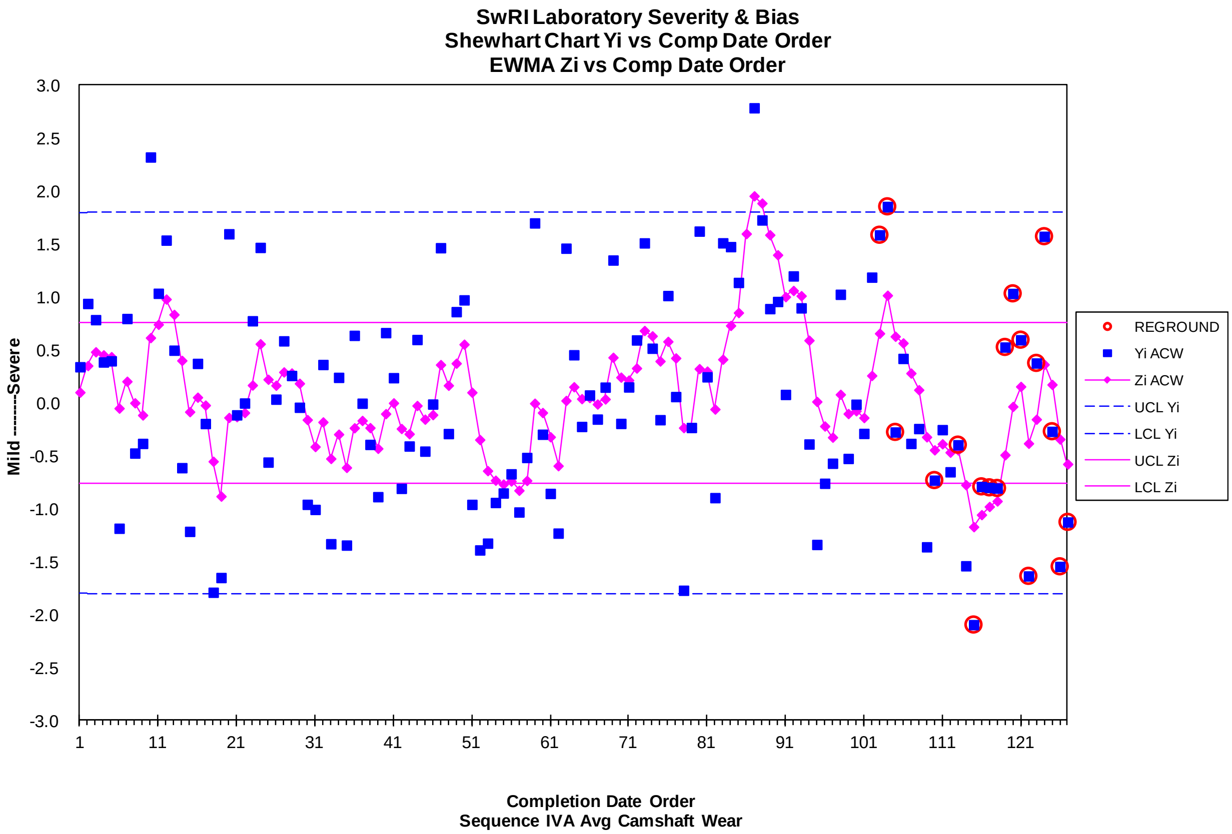


Figure 9: Plot of ACW Yi and ACW Zi for SwRI Reference Tests

The plot of ACW R_i and ACW Q_i from reference test results vs. completion date is shown in Figure 10. Any test conducted with a reground camshaft is indicated with a circle around the square. This data indicates that the introduction of the reground camshafts did not shift the precision of the test.

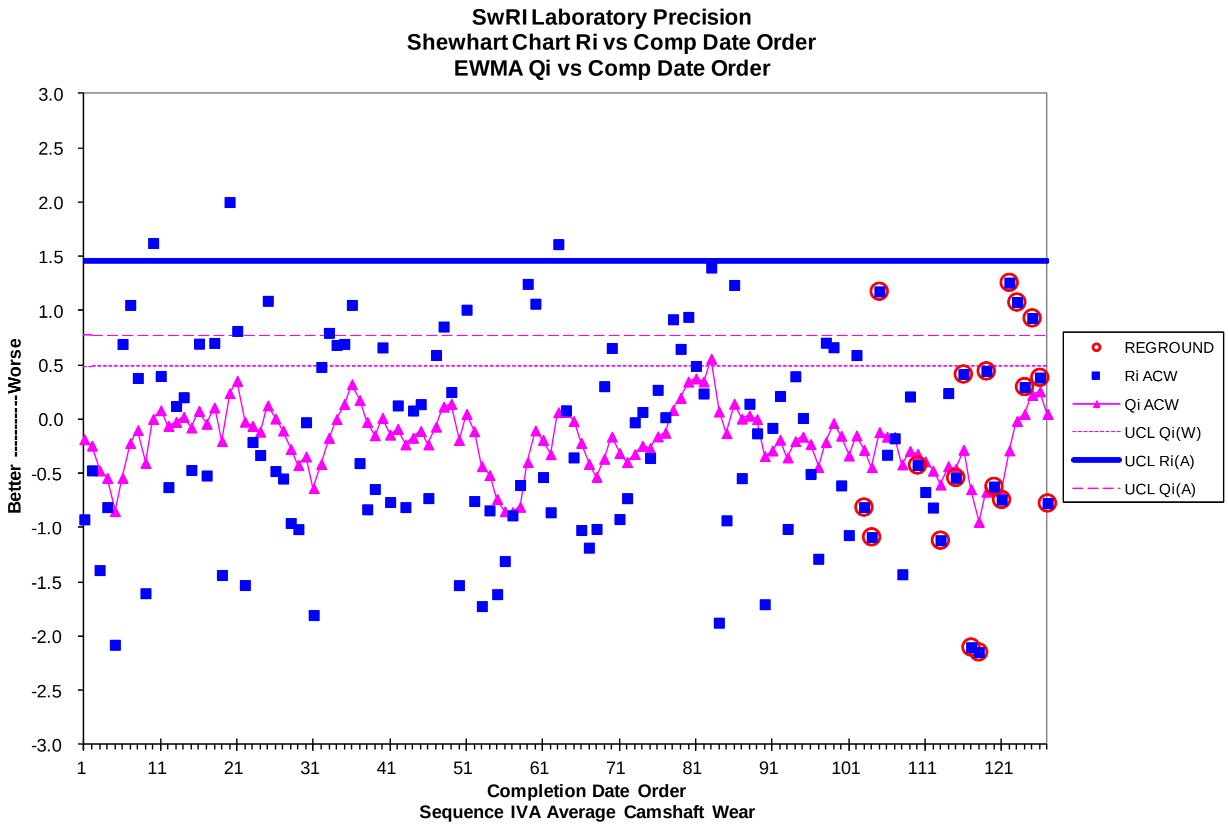


Figure 10: Plot of ACW Ri and ACW Qi for SwRI Reference Tests

The plot of ACW Y_i for industry and SwRI reference test results from December 2009 through January 2013 is shown in Figure 11.

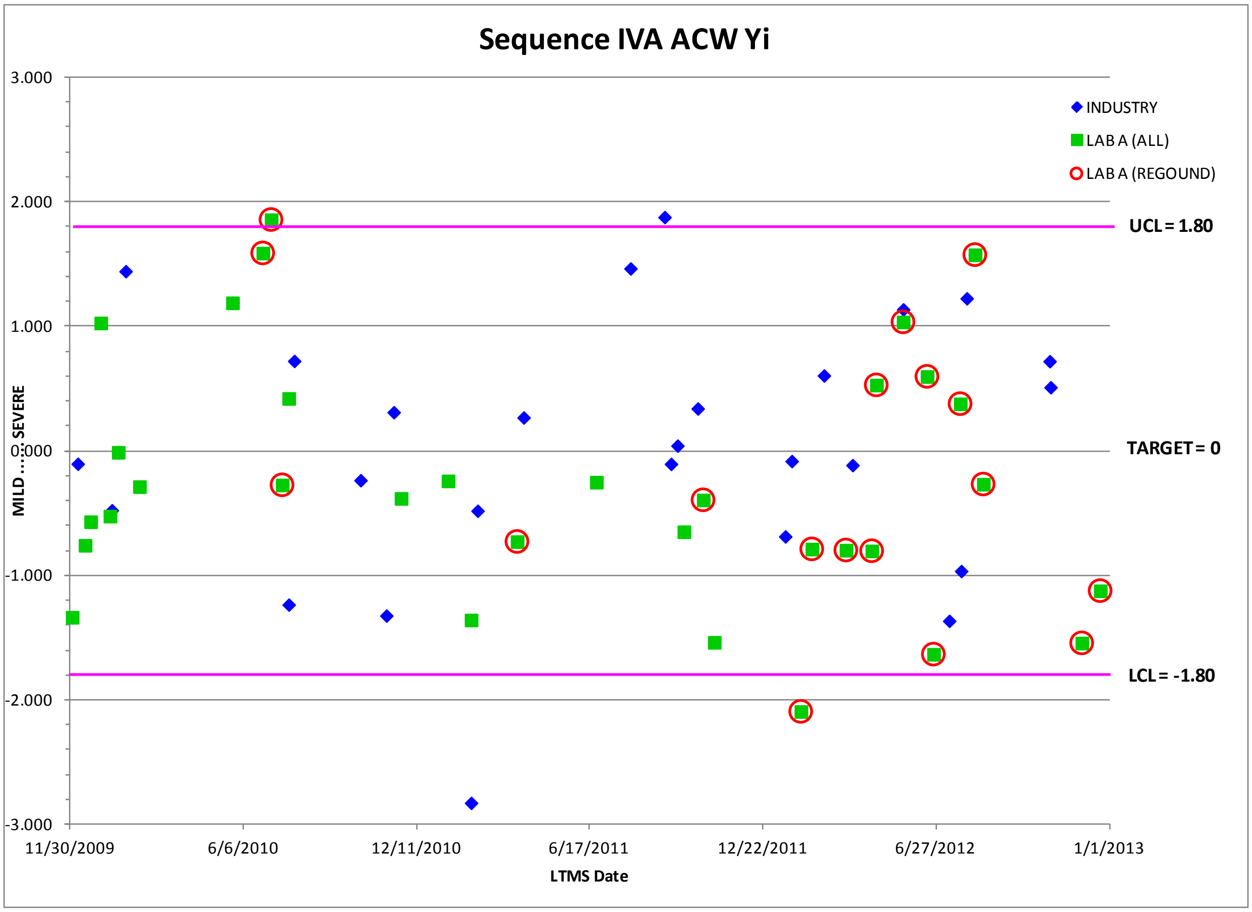


Figure 11: Plot of Yi vs. Date of Industry and SwRI (Lab A) Reference Oil Tests

SwRI reference tests are indicated by the squares, and any test conducted with a reground camshaft is indicated with a circle around the square. Results from other labs within the industry are indicated by the diamonds. Note that the scatter for all data within this timeframe falls within similar boundaries. This data indicates that the regrinding had no impact on the reference oils performance.

The LTMS severity analysis plot of ACW Z_i for industry and SwRI reference test results from December 2009 through January 2013 is shown in Figure 12.

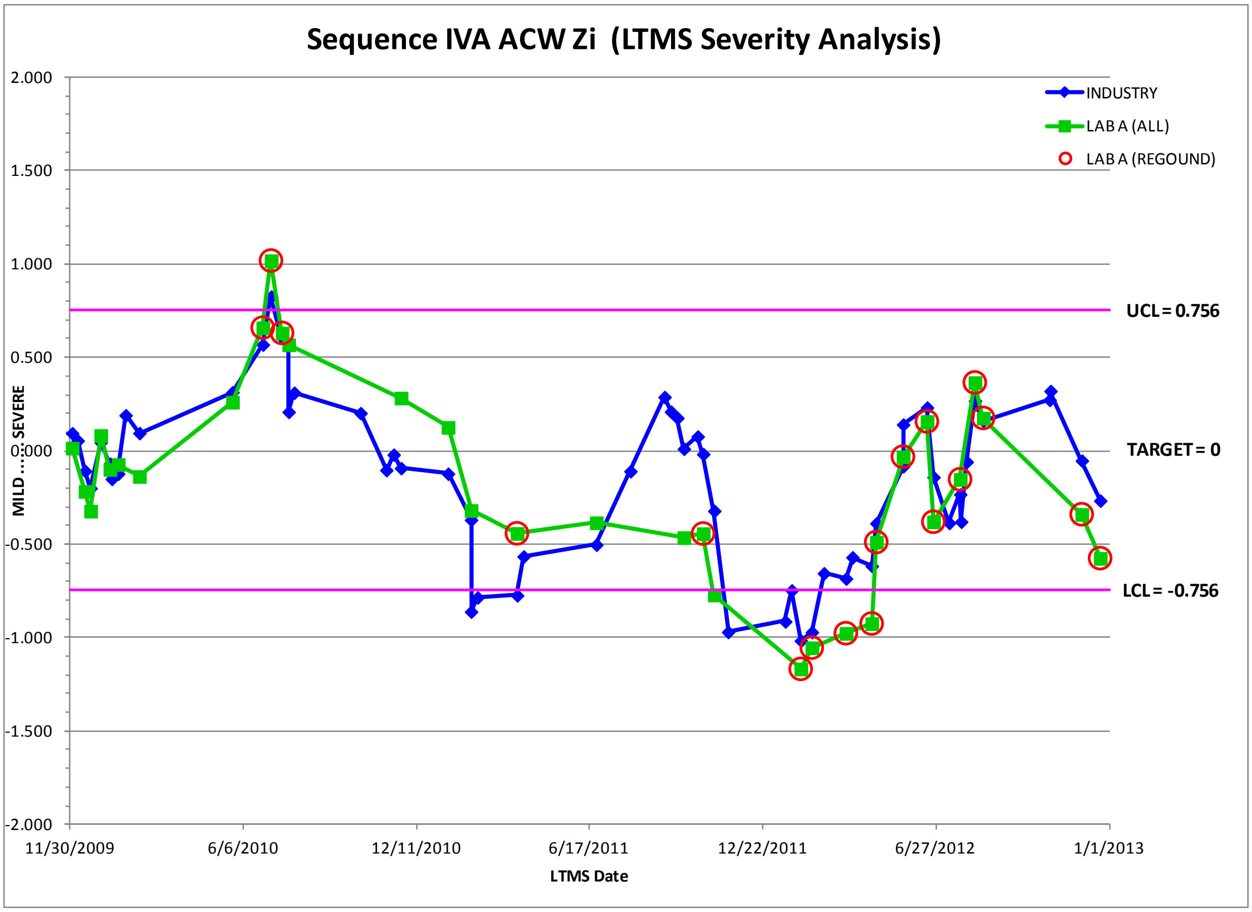


Figure 12: Plot of ACW Zi vs. Date of Industry and SwRI (Lab A) Reference Oil Tests

SwRI's lab severity trend is indicated by the green line (any test conducted with a reground camshaft is indicated with a circle around the square). The industry's severity trend is indicated by the blue line. Note that the trends of SwRI's lab severity and the industry's severity, within this timeframe, follow similar patterns. This data indicates that the regrinding had no impact on severity trends.

The LTMS precision analysis plot of ACW Q_i for industry and SwRI reference test results from December 2009 through January 2013 is shown in Figure 13.

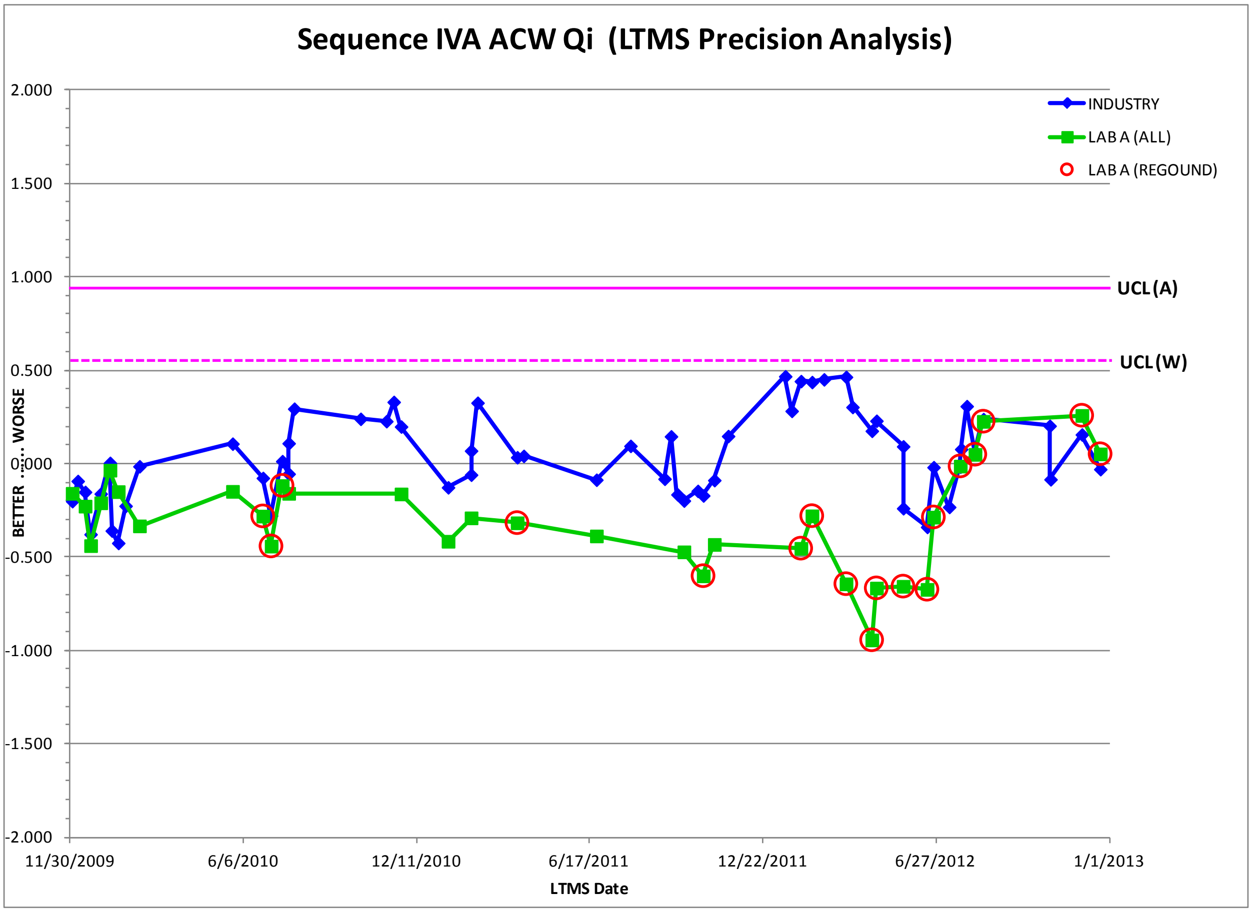


Figure 13: Plot of ACW Qi vs. Date of Industry and SwRI (Lab A) Reference Oil Tests

SwRI's lab precision trend is indicated by the green line (any test conducted with a reground camshaft is indicated with a circle around the square). The industry's precision trend is indicated by the blue line. Note that the trends of SwRI's lab precision and the industry's precision, within this timeframe, follow similar patterns. This data indicates that the regrinding had no impact on precision trends.

Conclusions

SwRI believes that regrinding camshafts that exhibit the convex lobe surface anomaly is necessary to produce accurate and repeatable ACW results, does not impact test severity when utilizing the standard wear measurement technique, and is necessary in order to sustain this test with the hardware currently in inventory at some laboratories and possibly the hardware that will be purchased by multiple test laboratories in the near future. The only alternative to regrinding camshafts that exhibit convex lobes is to attempt pre-test and post-test measurements using the overlay technique. Nissan cannot guarantee that future camshafts will not have the convex problem[3]. Camshafts that exhibit the convex lobe surface anomaly and are not measured using the overlay technique would produce mild test results resulting in either a lab's inability to successfully reference or a lab's potential to pass failing candidate oils.

At the time that the decisions were made to regrind camshafts, SwRI believed it was taking the proper technical approach to correct a fundamental problem with the Sequence IVA test hardware available to SwRI and to conduct proper Sequence IVA tests for calibration purposes and for SwRI clients. SwRI used an industry approved vendor to regrind the camshafts, SwRI proved the proper performance of the reground camshafts with official reference oil tests, SwRI introduced the reground camshafts from each lot with official reference oil tests and SwRI conducted the candidate oil tests with the same reground camshafts that SwRI referenced with. SwRI's interpretation of ASTM D6891 Sequence IVA test procedure is such that we did not violate the technical intent of the test procedure by incorporating the pre-test/post-test overlay wear measurement method or by restoring the camshaft lobes of the lots in question, to match those manufactured in 2008 and prior years, through regrinding. But in hindsight, SwRI recognizes that it did not follow proper ASTM protocol for implementing this technical approach.

[3] Confirmed during February 4, 2013 meeting with Takumaru Sagawa of Nissan.

APPENDIX A – Detailed Data

Measurement of convex lobe camshaft using standard measurement method										
Position	Cylinder	Lobe Number	14° BTC Wear, µm	10° BTC Wear, µm	4° BTC Wear, µm	0° (Nose) Wear, µm	4° ATC Wear, µm	10° ATC Wear, µm	14° ATC Wear, µm	Lobe Wear, µm
Intake	1	1	11.49	12.27	14.07	18.16	18.99	14.47	11.00	100.45
		3	7.63	9.54	10.22	12.28	11.45	9.73	4.22	65.07
	2	4	5.43	5.60	4.72	4.68	4.21	4.31	3.52	32.47
		6	7.45	10.07	10.74	11.63	11.98	11.86	2.00	65.73
	3	7	11.63	12.11	14.06	17.54	18.54	14.21	11.17	99.26
		9	5.19	9.84	12.13	13.77	12.58	7.18	1.64	62.33
	4	10	10.72	10.42	14.50	17.76	16.20	16.54	6.66	92.80
		12	9.59	12.85	9.67	12.08	9.15	6.89	3.79	64.02
	Max of Intake		11.63	12.85	14.50	18.16	18.99	16.54	11.17	100.45
	Avg. of Intake		**8.64**	**10.34**	**11.26**	**13.49**	**12.89**	**10.65**	**5.50**	**72.77**
Exhaust	1	2	1.14	8.86	7.36	6.7	6.81	3.7	2.52	37.09
	2	5	17.19	17.83	15.18	17.61	13.76	13.13	12.02	106.72
	3	8	9.56	12.95	15.54	12.97	10.43	7.06	4.84	73.35
	4	11	5.2	6.11	7.1	10.23	10.06	8.7	8.03	55.43
	Max of Exhaust		17.19	17.83	15.54	17.61	13.76	13.13	12.02	106.72
	Avg. of Exhaust		**8.27**	**11.44**	**11.30**	**11.88**	**10.26**	**8.15**	**6.85**	**68.15**
Over-all Maximum			17.19	17.83	15.54	18.16	18.99	16.54	12.02	106.72
Over-all Average			**8.52**	**10.70**	**11.27**	**12.95**	**12.01**	**9.82**	**5.95**	**71.23**

Measurement of convex lobe camshaft using overlay measurement method										
Position	Cylinder	Lobe Number	14° BTC Wear, µm	10° BTC Wear, µm	4° BTC Wear, µm	0° (Nose) Wear, µm	4° ATC Wear, µm	10° ATC Wear, µm	14° ATC Wear, µm	Lobe Wear, µm
Intake	1	1	11.98	12.72	14.52	19.09	19.51	15.38	11.21	104.41
		3	8.18	11.34	12.17	14.09	12.64	10.21	3.68	72.31
	2	4	9.37	9.43	8.18	7.61	6.23	5.96	12.10	58.88
		6	8.60	11.76	12.47	13.31	13.13	13.35	1.80	74.42
	3	7	11.90	12.58	14.07	18.21	18.98	14.98	11.28	102.00
		9	7.27	12.24	14.00	15.19	13.71	8.30	1.57	72.28
	4	10	12.37	11.68	14.48	17.87	16.38	17.92	6.65	97.35
		12	12.25	14.68	10.84	12.77	10.32	8.36	1.08	70.30
	Max of Intake		12.37	14.68	14.52	19.09	19.51	17.92	12.10	104.41
	Avg. of Intake		**10.24**	**12.05**	**12.59**	**14.77**	**13.86**	**11.81**	**6.17**	**81.49**
Exhaust	1	2	1.30	10.63	10.32	9.33	7.29	4.21	2.68	45.76
	2	5	21.60	21.87	19.38	21.77	17.00	15.01	13.87	130.50
	3	8	10.98	15.01	16.81	15.07	11.21	7.19	5.99	82.26
	4	11	9.12	7.72	7.42	9.10	8.99	9.29	8.59	60.23
	Max of Exhaust		21.6	21.87	19.38	21.77	17	15.01	13.87	130.5
	Avg. of Exhaust		**10.75**	**13.81**	**13.48**	**13.82**	**11.12**	**8.92**	**7.78**	**79.69**
Over-all Maximum			21.60	21.87	19.38	21.77	19.51	17.92	13.87	130.50
Over-all Average			**10.41**	**12.64**	**12.89**	**14.45**	**12.95**	**10.85**	**6.71**	**80.89**

Table 1: Detailed Measurements of a Camshaft With Convex Lobes Using Standard Measurement Method and Overlay Measurement Method

Attachment 5

Sequence IVA

Test Hardware Report

Prepared by:

William A. Buscher III

January 24, 2013

San Antonio, Texas

Test Hardware Report

- Hardware Status:
  - All previous Nissan hardware orders have been completed
  - Industry currently using mixture of 2007 and 2009 test kits
  - Test hardware NOT secured through 2016
  - Usage rates in 2010, 2011 and 2012 have been much higher than projected when the final hardware order was placed back in 2009
    - Candidate testing doubled in last 6 months (N = 99 vs. 53)

Test Hardware Report

- Hardware Status:
  - Based on estimated usage rates and quantities currently on-hand at the laboratories, some labs will deplete hardware by late 2013 and industry will deplete hardware by mid 2014

Lab	A	B	C	F
Estimated Hardware Depletion	Late 2013	Mid 2014	N/A	Late 2013
Estimated Additional Runs Needed	352	148	N/A	70

  - Estimate hardware needed for ≈ 550 – 600 tests to be secured through 2016

Test Hardware Report

- Hardware Status:
  - SP chair has been in communication with Nissan discussing another Sequence IVA hardware solicitation to be offered to the ASTM test labs
  - Nissan indicated that the Sequence IVA Test Kit, p/n 13000-40F85 (camshafts, rocker arms, rocker shafts, oil filters, spark plugs), Engine Valve Regrind Kit p/n A1042-10C2K (gasket kit) and Assembled Cylinder Head p/n A1040-40F85 are out of production, but individual alternative components are available

Test Hardware Report

SPPS		Parts number		Name	Availability		
96-1332	13000 40F85			Test Kit	NO		
Composition of "Test kit 13000 40F85"							
		Parts number		Parts name	riginal parts numbe	lternative part	QTY
		A3020 40P01	A302040P01	CAM SHAFT ASSY	13020 40F01		1
		13252 40F10	1325240F10	SHAFT ROCKER	13252 40F10	13252 40F1A	1
		13245 40F10	1324540F10	SHAFT ROCKER	13245 40F10	13245 40F1A	1
		A3257 40F06	A325740F06	ROCKER VALVE	13257 40F06		4
		A3257 40F07	A325740F07	ROCKER VALVE	13257 40F07		4
		A3257 40F16	A325740F16	ROCKER VALVE	13257 40F16		2
		A3257 40F17	A325740F17	ROCKER VALVE	13257 40F17		2
		15208 H8904	15208H8904	FILTER ASSY OIL	15208 H8904	15208 H890C	3
		22401 30R15	2240130R15	PLUG SPARK	22401 30R15		4

Test Hardware Report

SPPS		Parts number	Name	Availability				
07-1123	A1042 10C2K		Gasket Kit	OK				
Composition of "Gasket kit A1042 10C2K"								
		Parts number	Parts name	Original parts number		Alternative parts		QTY
		11044 40Ｆ00	GSKT-CYL HEAD	11044 40Ｆ00	1104440Ｆ00	11044 40Ｆ10	1104440Ｆ10	1
		13207 Ｄ0111	SEAL-OIL,VALVE	13207 Ｄ0111	13207Ｄ0111	13207 53Ｆ00	1320753Ｆ00	2
		13207 42Ｌ00	SEAL-OIL,VALVE	13207 42Ｌ00	1320742Ｌ00			1
		13270 Ｆ4000	GSKT-ROCKER COVER	13270 Ｆ4000	13270Ｆ4000			1
		14035 40Ｆ10	GSKT MANIFOLD	14035 40Ｆ10	1403540Ｆ10			1
		14036 40Ｆ00	GSKT-EXH MAINF	14036 40Ｆ00	1403640Ｆ00			2

Test Hardware Report

SPPS		Parts number	Name		Availability	
97-0736	A1040 40F80		Head Assy		NO	
Composition of "Head assy A1040 40F80"						
		Parts number	Parts name	Original parts number	Alternative parts	QTY
		A1040 40F11	HEAD ASSY	A1040 40F11	11040 40F11	1
		13201 40F00	VALVE-INT	13201 40F00		8
		13202 40F01	VALVE-EXH	13202 40F01		4
		13205 40F00	SEAT VALVE SPRING,OUTER	13205 40F00		8
		13205 40F10	SEAT VALVE SPRING,OUTER	13205 40F10	13205 40F1A	4
		13206 40F01	SEAT VALVE SPRING,INNER	13206 40F01	13206 40F0A	8
		13206 40F10	SEAT VALVE SPRING,INNER	13206 40F10	13206 40F1A	4
		13209 40F00	RET-VALVE,SPR	13209 40F00		8
		13209 40F10	RET-VALVE,SPR	13209 40F10		4
		13210 40F00	COLLET-VALVE,SPR	13210 40F00		24
		13211 40F01	SPRING SET-VALVE,INT	13211 40F01 = 13203 40F01 + 13204 40F01		8
			SPRING -VALVE,INT	13203 40F01		8
			SPRING -VALVE,INT	13204 40F01		8
		13211 40F11	SPRING SET-VALVE,EXH	13211 40F11 = 13203 40F11 + 13204 40F11		4
			SPRING -VALVE,EXH	13203 40F11		4
			SPRING -VALVE,EXH	13204 40F11		4
		13207 53F00	SEAL-LIP, INT VALVE	13207 53F00	13207 D0111	8
		13207 40F00	SEAL-LIP, EXH VALVE	13207 40F00	13207 42L00	4

Test Hardware Report

- Hardware Status:
  - Nissan indicated that individual components listed in the previous slides can be made available in the quantities required, as indicated by the ASTM test labs
  - Nissan is working on pricing and timing
  - Takumaru Sagawa of Nissan Japan will be meeting with the SP chair on Monday, 2/4/13, to further discuss Sequence IVA hardware supply

Test Hardware Report

- Other Hardware Concerns:
  - Oil coolers
  - Distributors
  - Wiring harnesses
  - ECUs
  - Other?

Test Hardware Report

- Severity of Remaining Camshaft Batches:
  – 070917A, referenced, 0.9 std. dev. severe
  – 080610, referenced, 0.5 std. dev. mild
  – 2009, referenced, 0.1 std. dev. severe
  – NK9X230, referenced, 1.2 std. dev. mild
  – NK04120, referenced, 0.2 std. dev. mild
  – NK05190, referenced, 1.3 std. dev. mild
  – NK05110, not referenced, 4.3 std. dev. Mild
    - 1 result, 1 lab
  – NK9Y100, not referenced, 2.9 std. dev. Mild
    - 3 results, 1 lab

Test Hardware Report

Camshaft Batch	Lab A	Lab B	Lab C	Lab F
070917A		X		X
080610	Depleted		X	
2009	Depleted	X		
NK9X230	X			
NK04120	X	X		
NK05190	X	X		
NK05110	X			
NK9Y100	X			

Sequence IVA 1006-2 Results

Sequence IV Surveillance Panel

January 24, 2013

Summary of Results

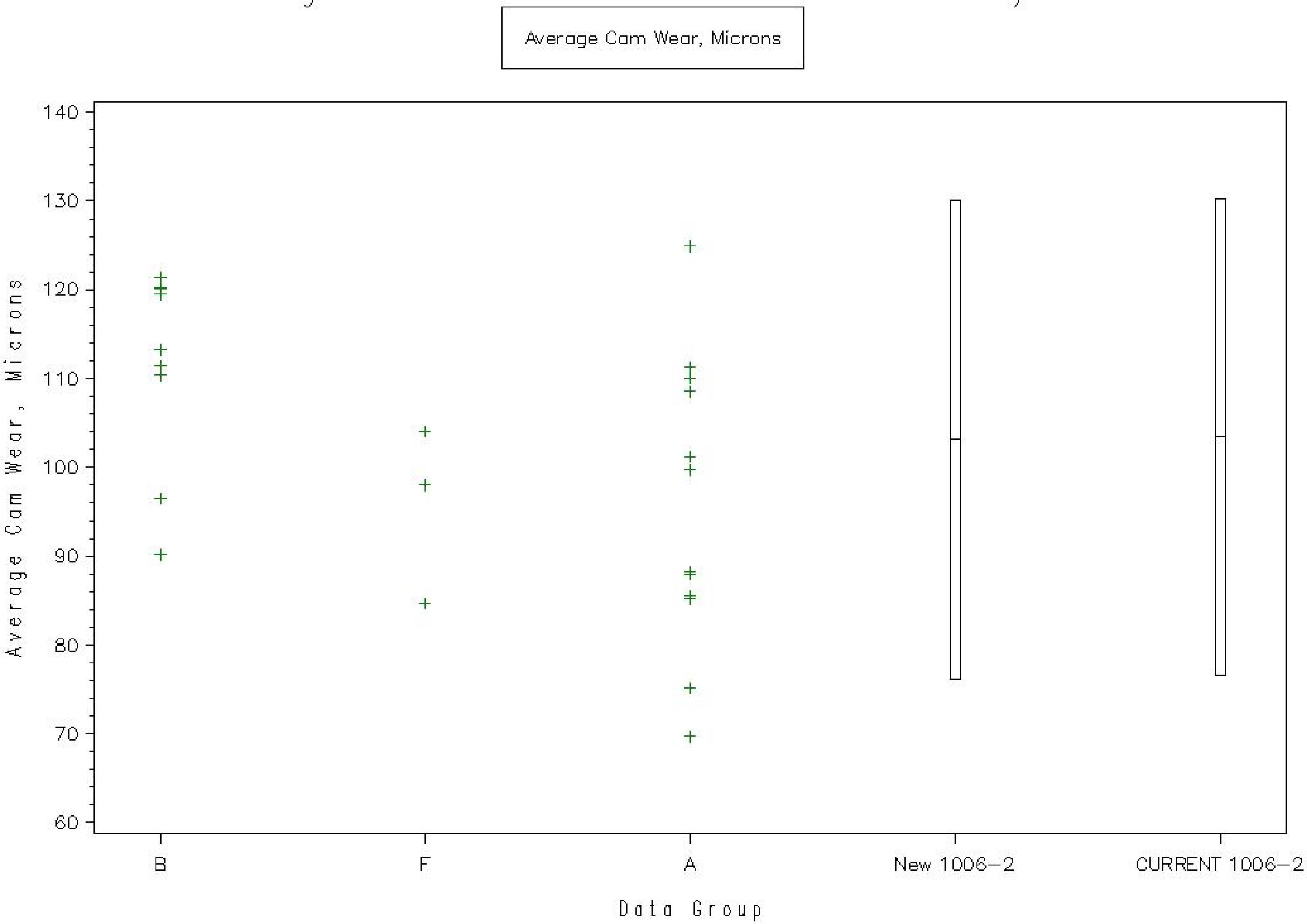
- 25 tests reported from three labs
- Little change in mean and standard deviation.
- Mean (n = 15) 103.68 Updated 103.16
- s (n = 15) 13.68 Updated 13.75
- Summary in next few slides

Summary of Results

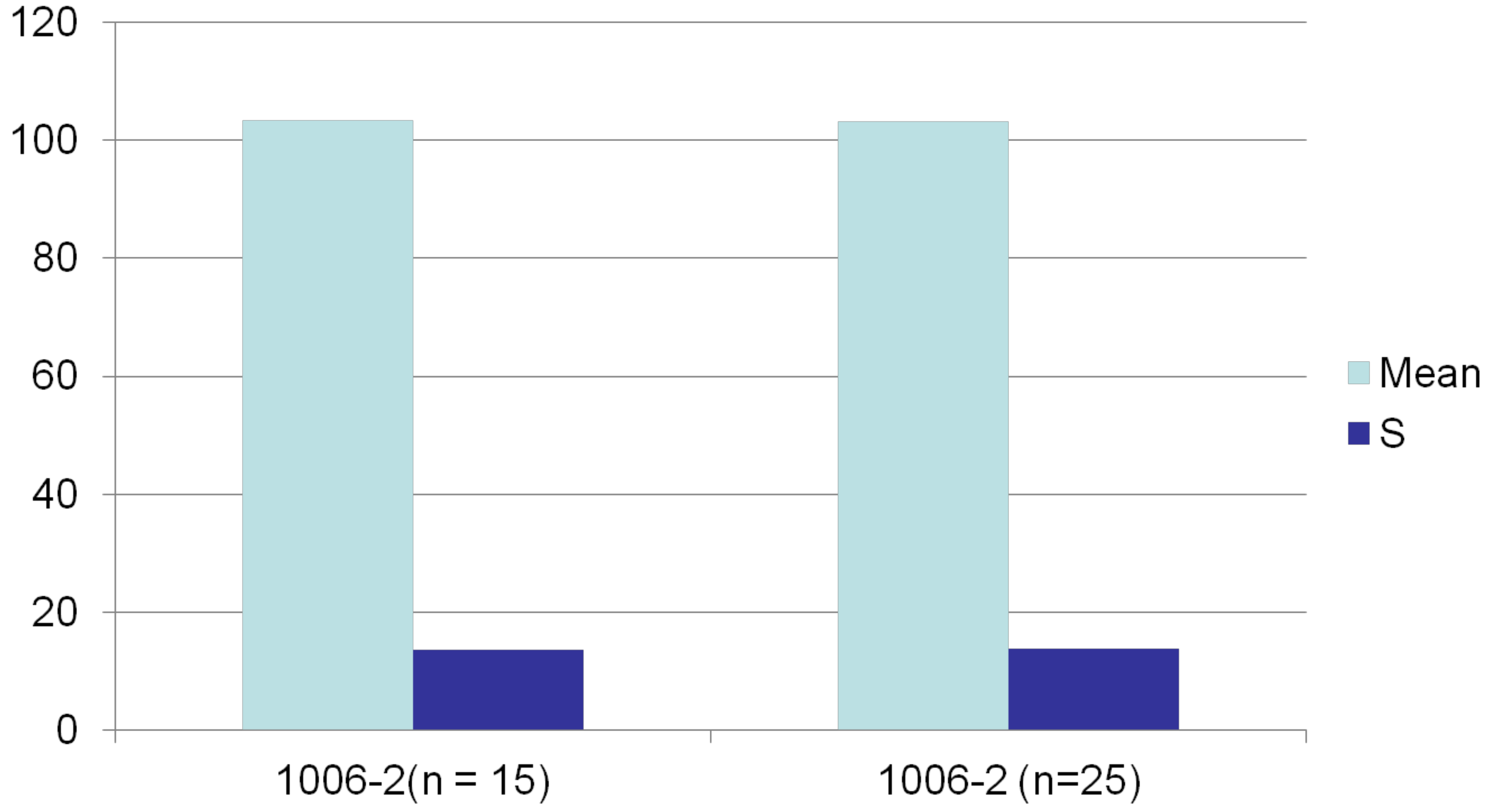
TESTKEY	LTMSLAB	LTMSDATE	IND	VAL	ACW	SA	Severity Adjusted Result
80991	B	20110809	1006-2	AG	120.24	0	120.24
84235	F	20111002	1006-2	AG	104.06	0	104.06
78808	A	20111009	1006-2	AG	101.24	0	101.24
84565	A	20111110	1006-2	AG	75.19	9.65	84.84
86108	B1	20120208	1006-2	AG	96.55	0	96.55
85064	A	20120213	1006-2	AC	85.48	16.567	102.047
86679	B1	20120226	1006-2	AC	111.47	0	111.47
86688	A	20120321	1006-2	AC	85.31	15.357	100.667
84326	F	20120328	1006-2	AC	98.05	0	98.05
86689	A	20120418	1006-2	AC	85.2	14.538	99.738
86690	A	20120423	1006-2	AC	110.04	0	110.04
87577	A	20120522	1006-2	AC	119.48	0	119.48
86680	B1	20120522	1006-2	AC	121.37	0	121.37
87578	A	20120616	1006-2	AC	111.32	0	111.32
87579	A	20120624	1006-2	AC	69.72	0	69.72
86868	F	20120711	1006-2	AC	84.72	0	84.72
88335	A	20120723	1006-2	AC	108.56	0	108.56
86871	B1	20120724	1006-2	AC	90.19	0	90.19
86682	B1	20120730	1006-2	AC	120.15	0	120.15
88336	A	20120808	1006-2	AC	124.93	0	124.93
88337	A	20120817	1006-2	AC	99.73	0	99.73
88807	B1	20121028	1006-2	AC	113.24	0	113.24
88806	B1	20121029	1006-2	AC	110.38	0	110.38
89508	A	20121202	1006-2	AC	88.28	0	88.28
91518	A	20121222	1006-2	AC	88.02	0	88.02

Figure 1

Sequence IVA (Reference Oil 1006-2)
Test Target Data Set and Shewart Severity Limits



Summary of Targets



A Program of ASTM International

DRIVELINE EFFECTS ON DYNAMIC TORSIONAL VIBRATION ON SEQUENCE IVA ENGINE STAND

Eric Liu, Research Engineer

Southwest Research Institute

January 24, 2013

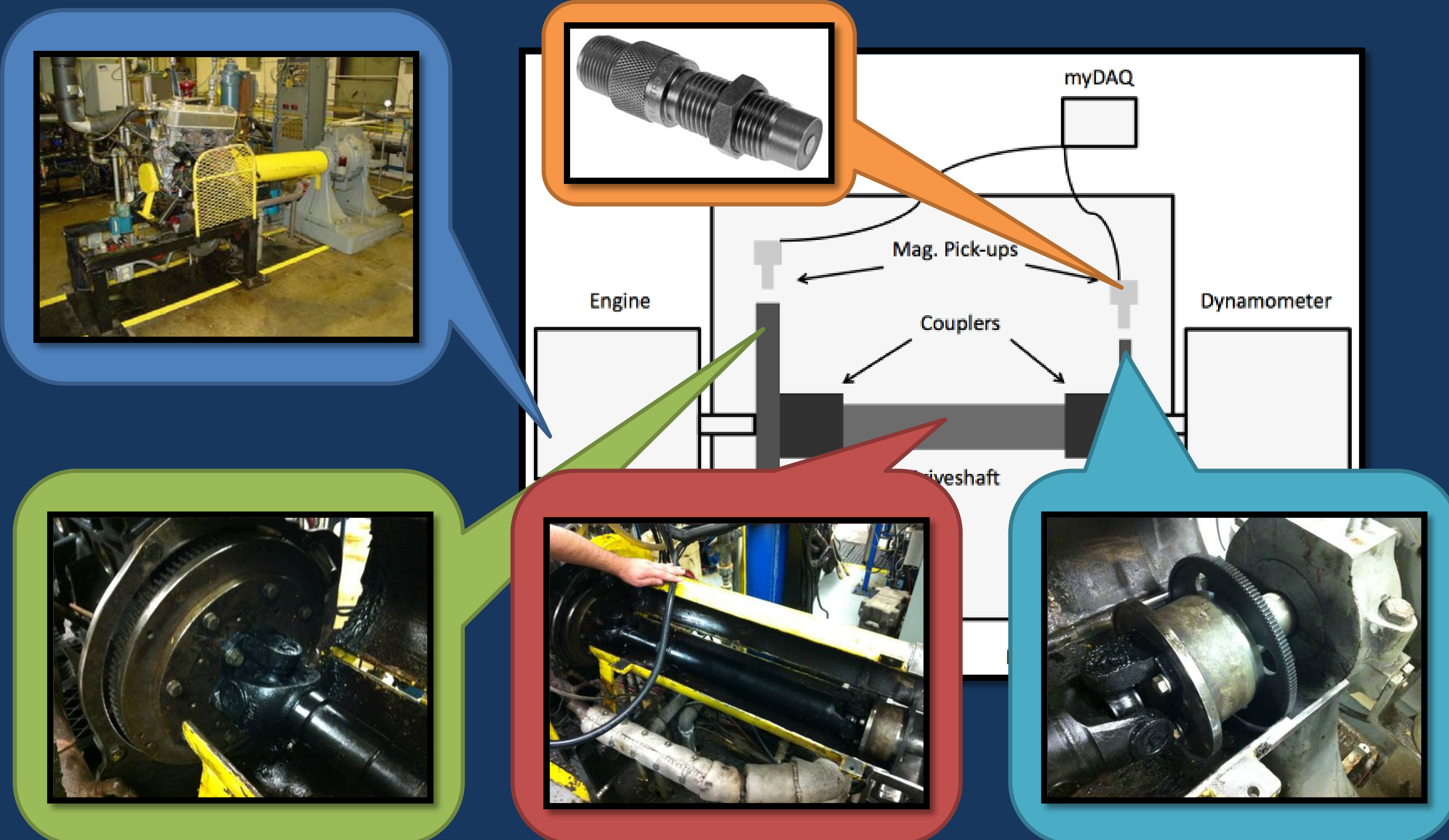
Background
Sequence IVA Test Severity Issues

- Engine lubricant testing labs unable to discriminate between a severe wear lubricant and a mild wear lubricant
- Unable to produce severe wear on cam lobes
- Severity Task Force formed in 2008-2009

Hypothesis

- Demonstration showed different driveline configurations allowed labs to regain discrimination in cam lobe wear
- **Driveline of different *stiffness* changed the *torsional vibration dynamics* of the test stand**
- ***Torsional vibration dynamics* have a direct effect on *cam lobe wear***

Experimental Setup



Measuring Driveshaft Twist

Flywheel

<u>120 teeth</u>

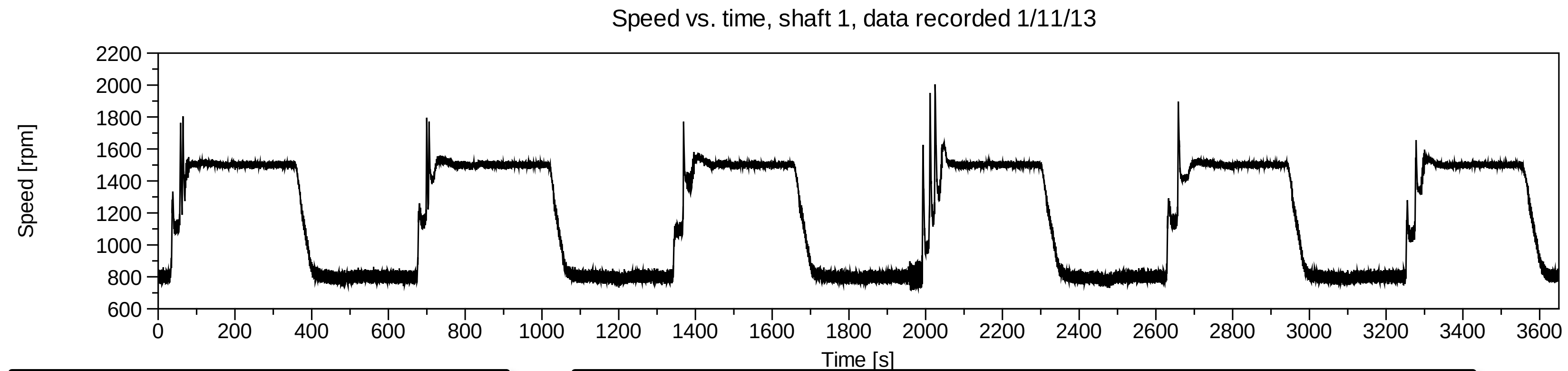
0.0524 rad/tooth

Dyno-Side Gear

<u>160 teeth</u>

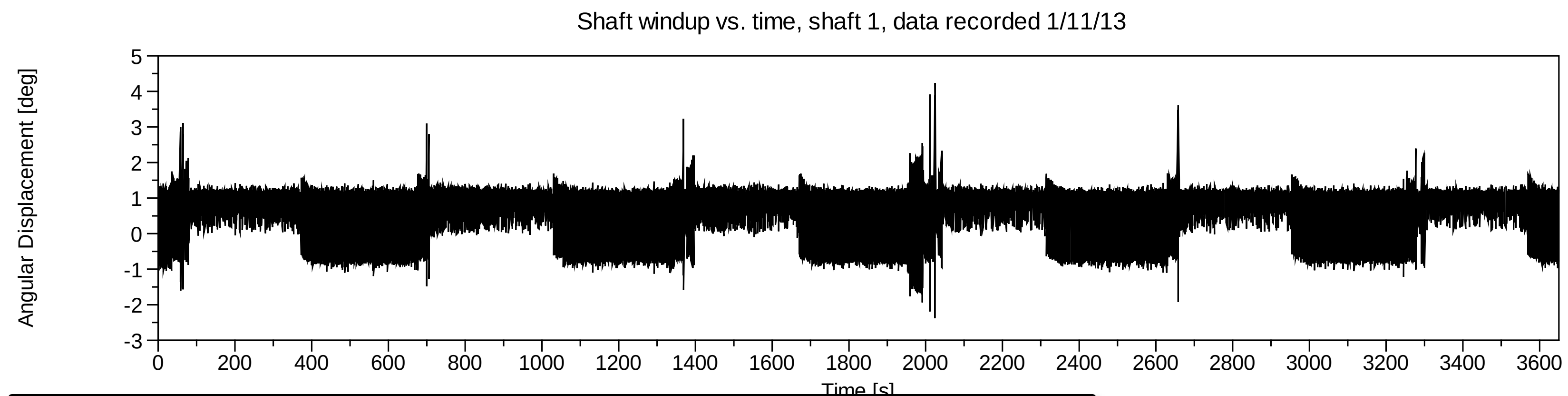
0.0393 rad/tooth

Calculating Shaft Wind-Up



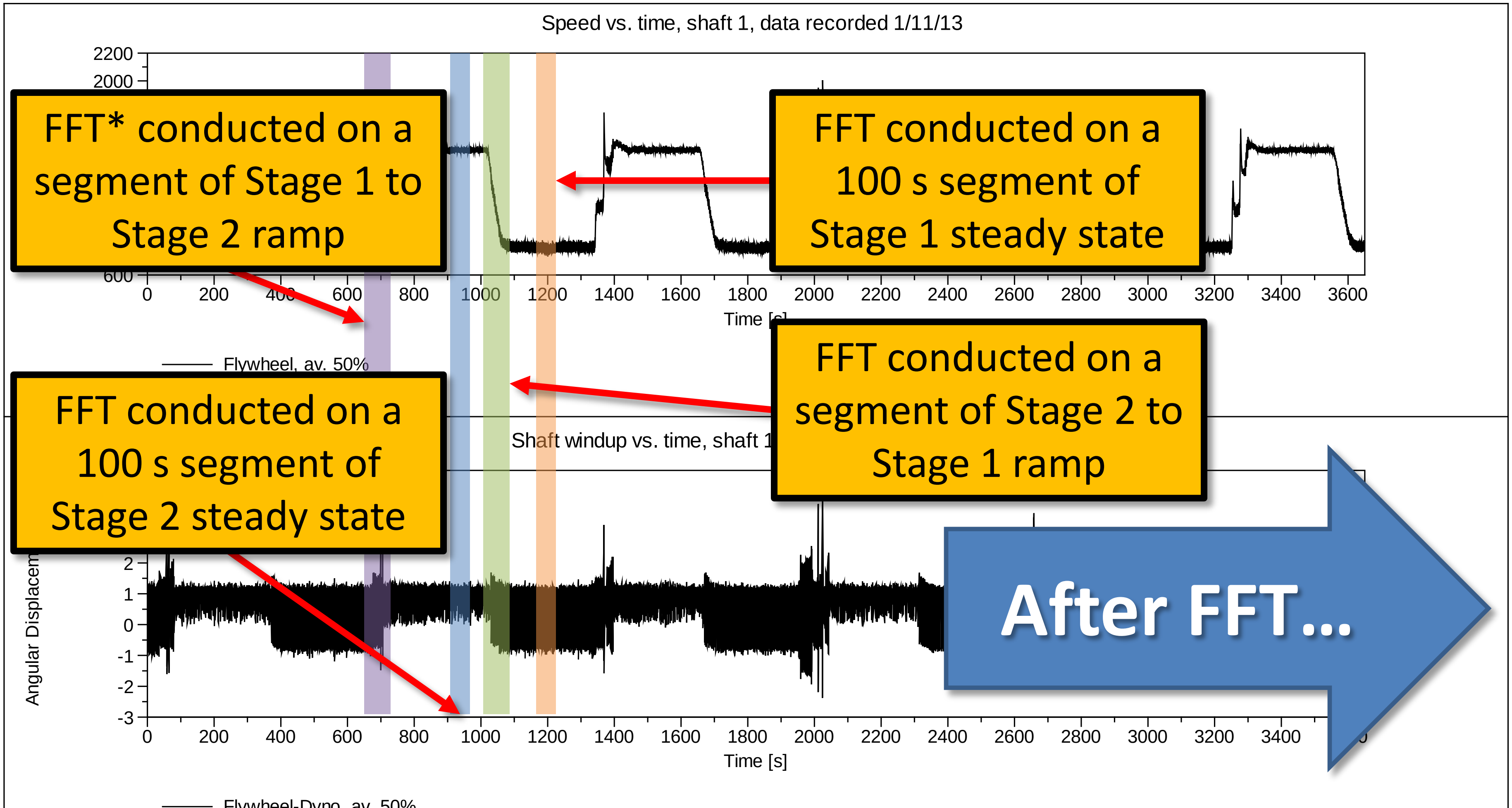
Flywheel Speed

Dynamometer hub speed is similar…



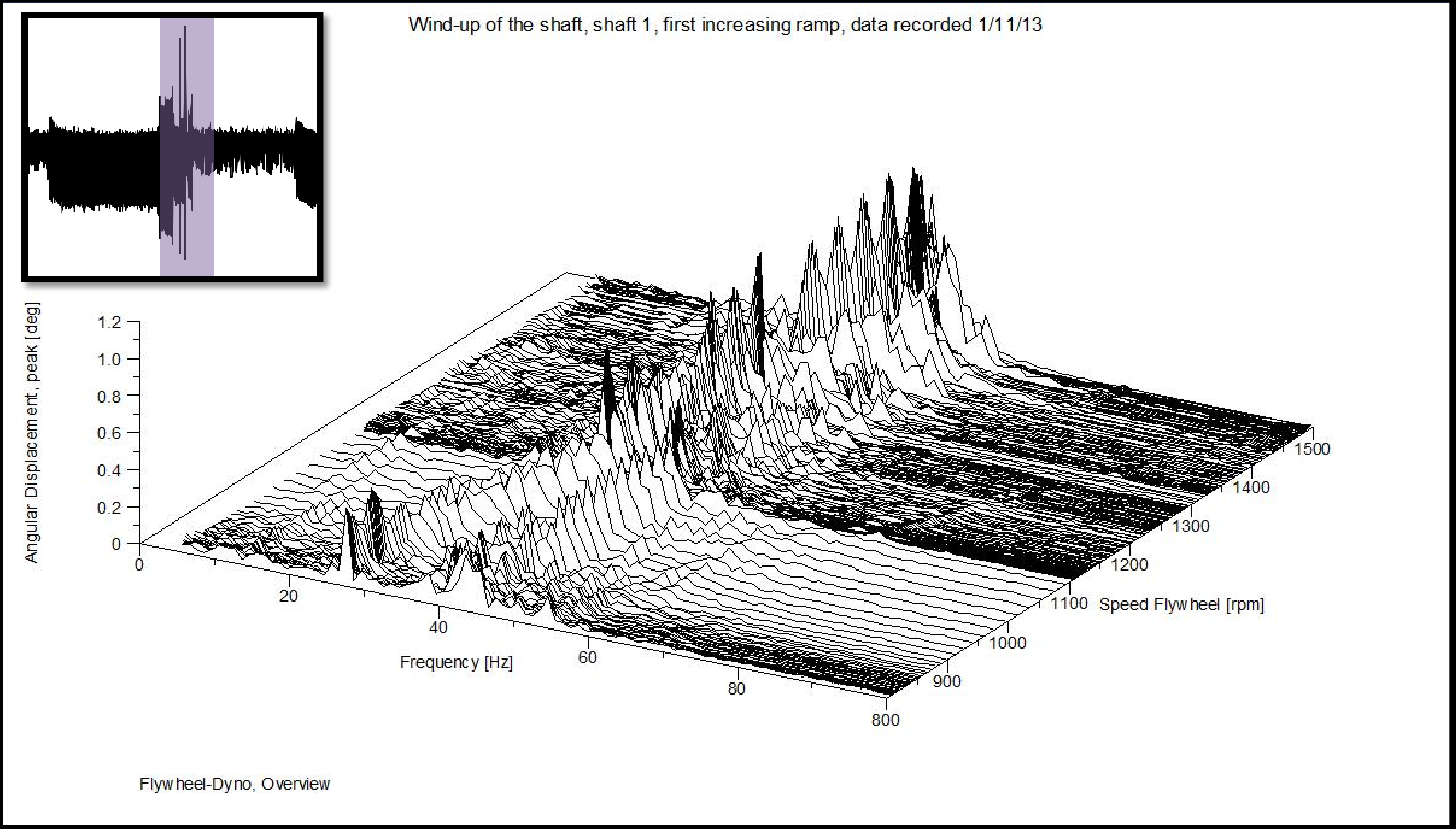
Flywheel Speed – Dynamometer Hub Speed

Obtaining Frequency Content

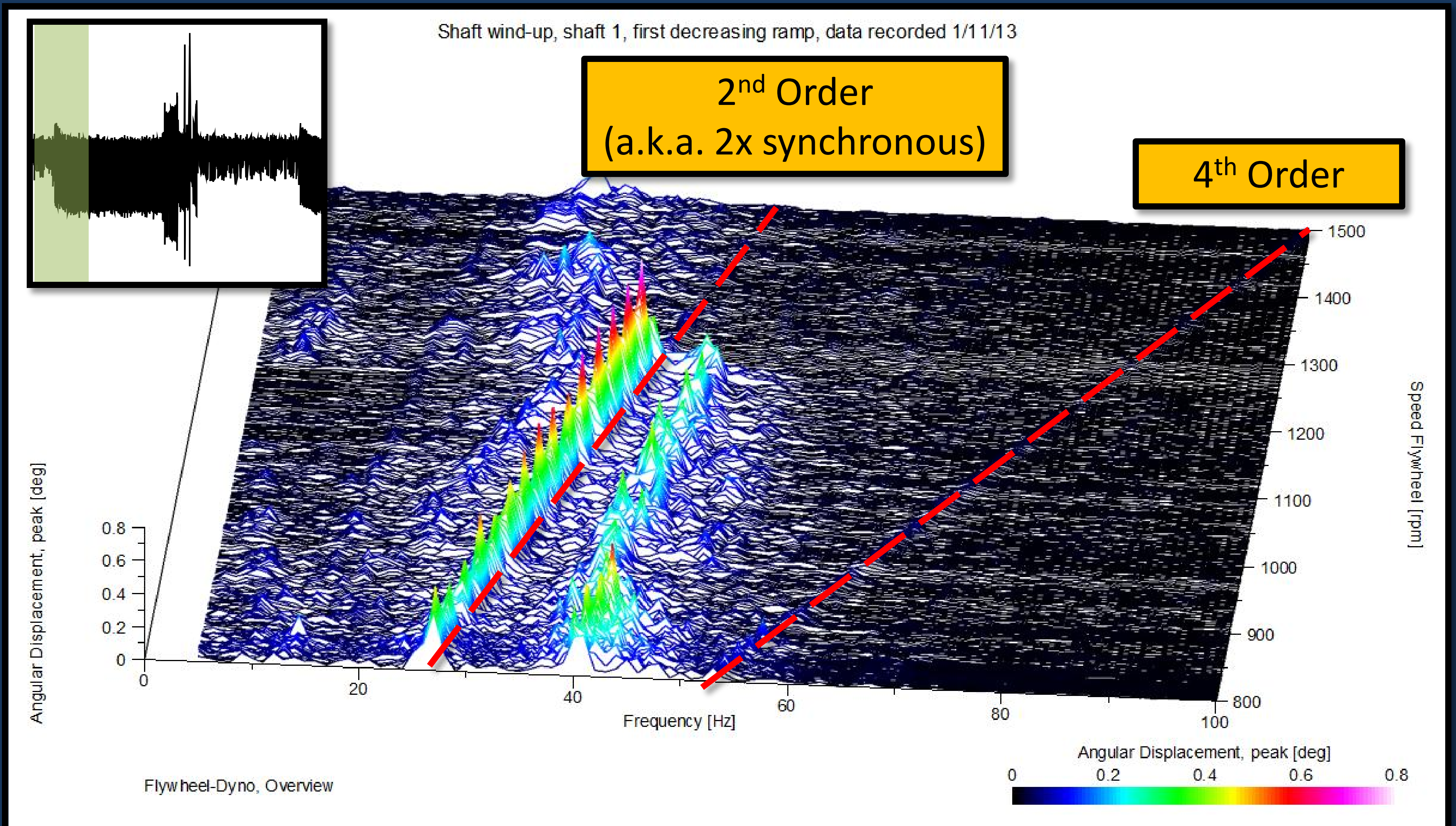


* FFT = Fast Fourier Transform; used to extract frequency content of an oscillating system

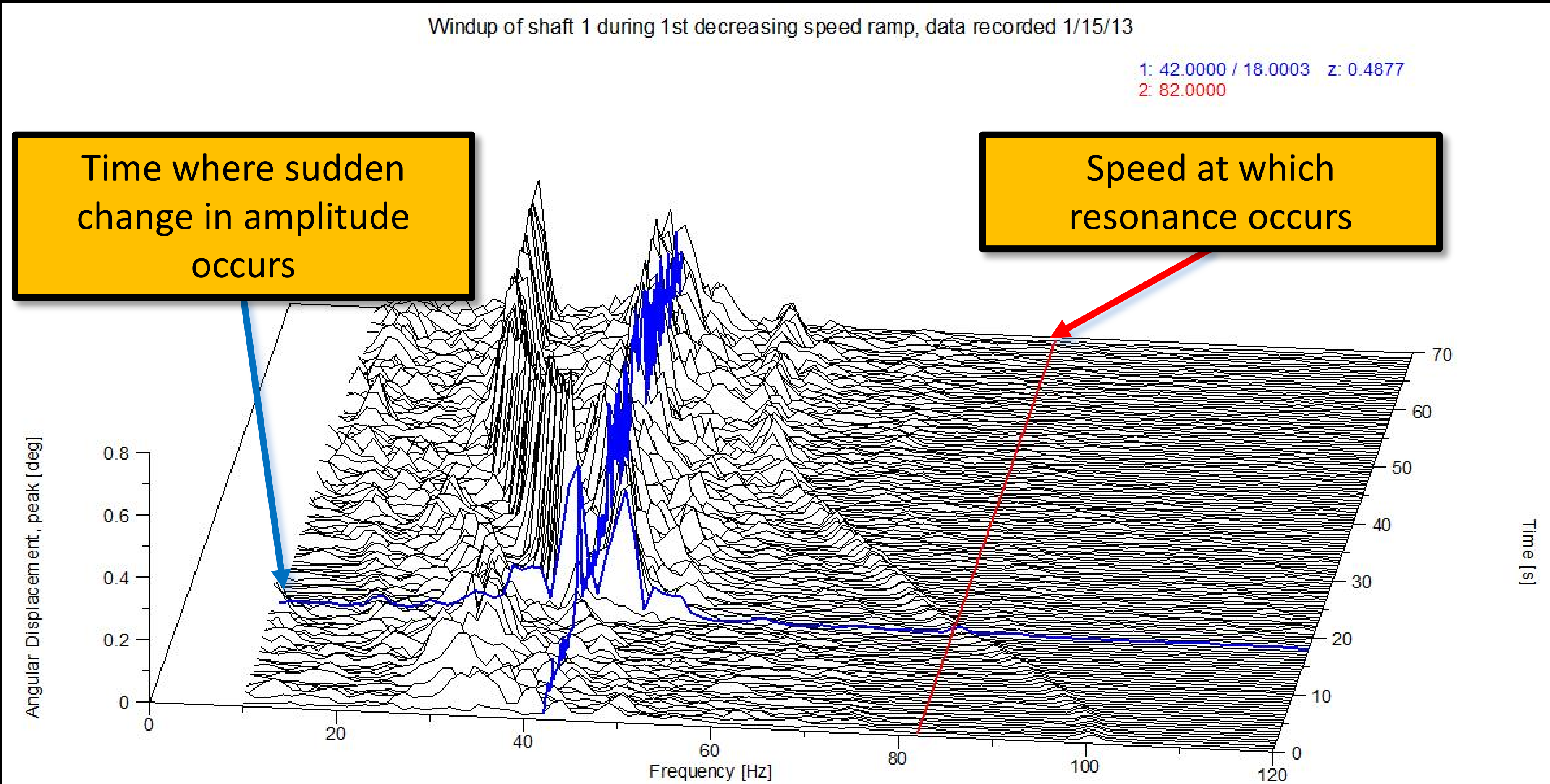
Frequency Content – 1 to 2 Ramp



Frequency Content – 2 to 1 Ramp



Natural Frequency on Ramps



Resonant speed = 82Hz = 1230rpm

Objective 1

- To quantify differences in torsional vibration dynamics in the engine test stand system between drivelines of different stiffnesses

Solid Shaft

Damped Shaft

Comparison of ω_n at Different Driveshaft Stiffness

Operation	Observed Resonant Frequency	
	Solid Shaft	Damped Shaft
1-2 Ramp	51Hz	39Hz
2-1 Ramp	44Hz	36Hz

- Natural frequency (ω_n) measured during the 1-2 ramp and the 2-1 ramps are not the same
- HOW?

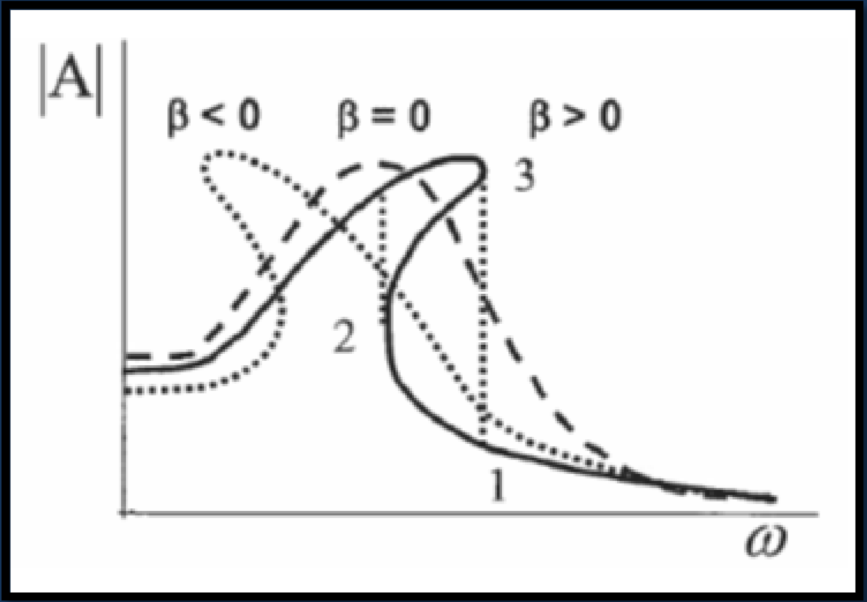
Comparison of ω_n at Different Driveshaft Stiffness

Operation	Observed Resonant Frequency	
	Solid Shaft	Damped Shaft
1-2 Ramp	51Hz	39Hz
2-1 Ramp	44Hz	36Hz

- **Supposition:** Lash in splines in the driveshaft result in a non-linear spring system
  - Initial conditions (twist angle) can change the frequency of oscillation
- Not as prominent in damped shaft
  - Stiffness of damped shaft is dominated by rubber

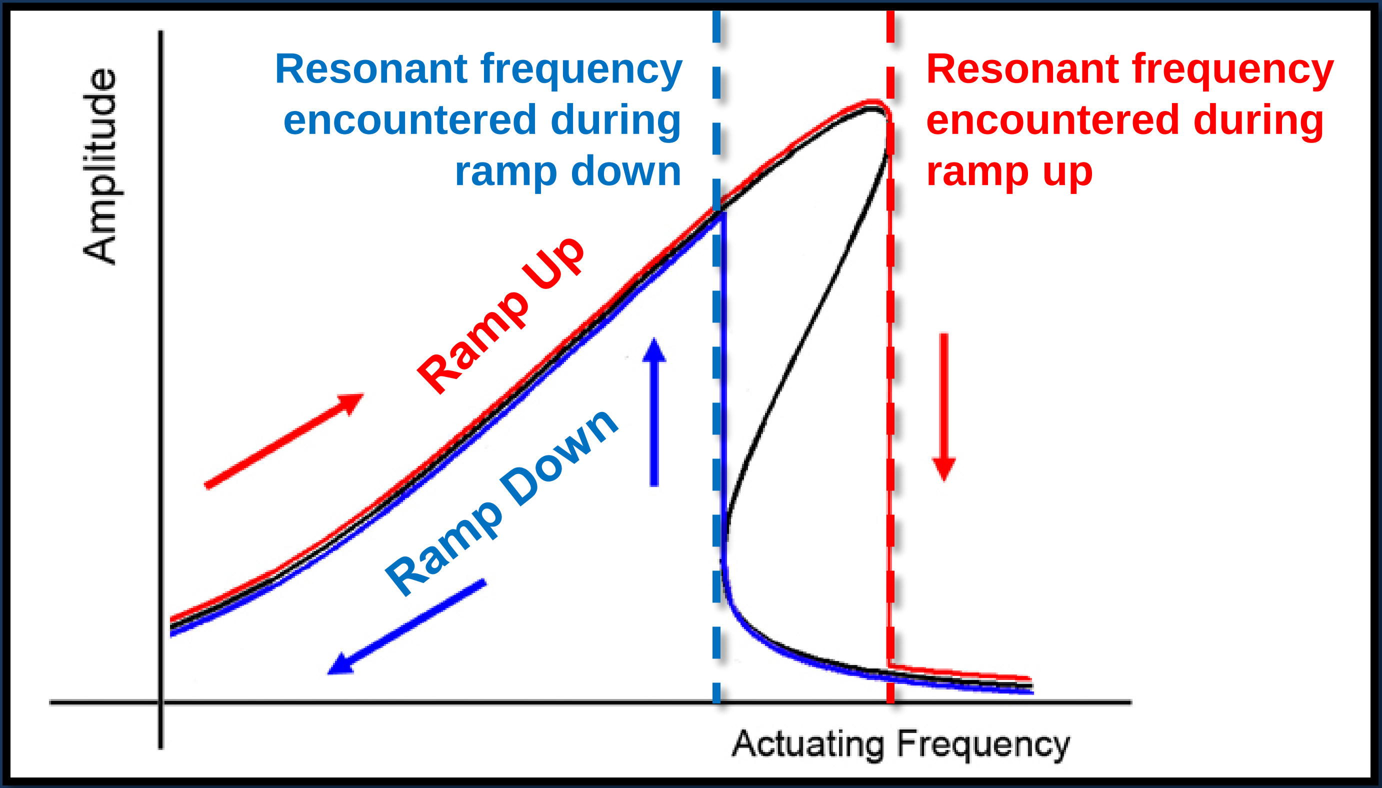
Non-Linear Spring System

- Duffing equation
  - $m\ddot{x} + c\dot{x} + \alpha x + \beta x^3 = \mathrm{F}\cos\omega t$
  - $\beta = 0$, linear spring
  - $\beta > 0$, hardening spring
  - $\beta < 0$, softening spring

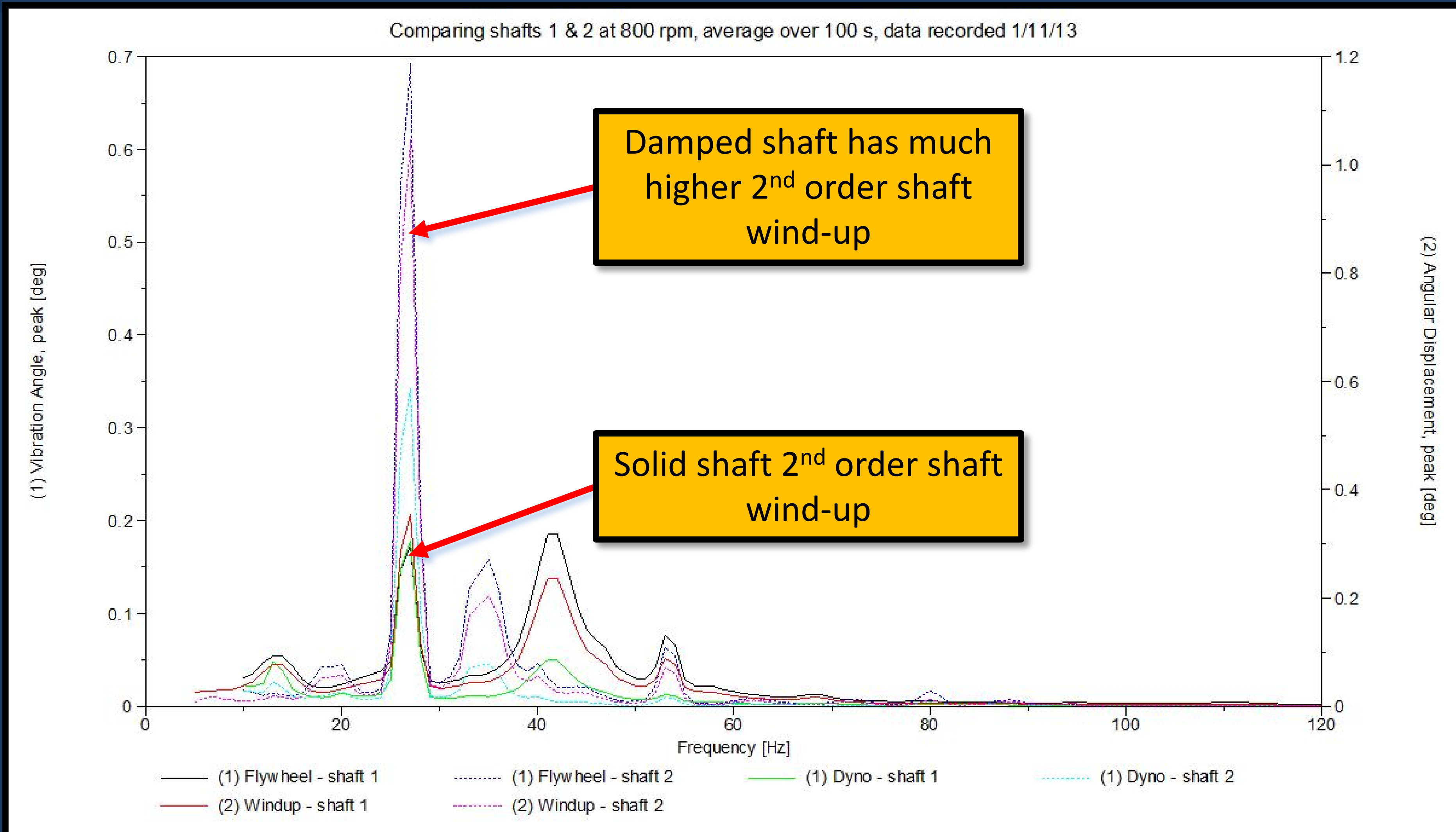


Hardening Spring System

- Driveshaft vibration responses resemble hardening spring ($\beta > 0$)



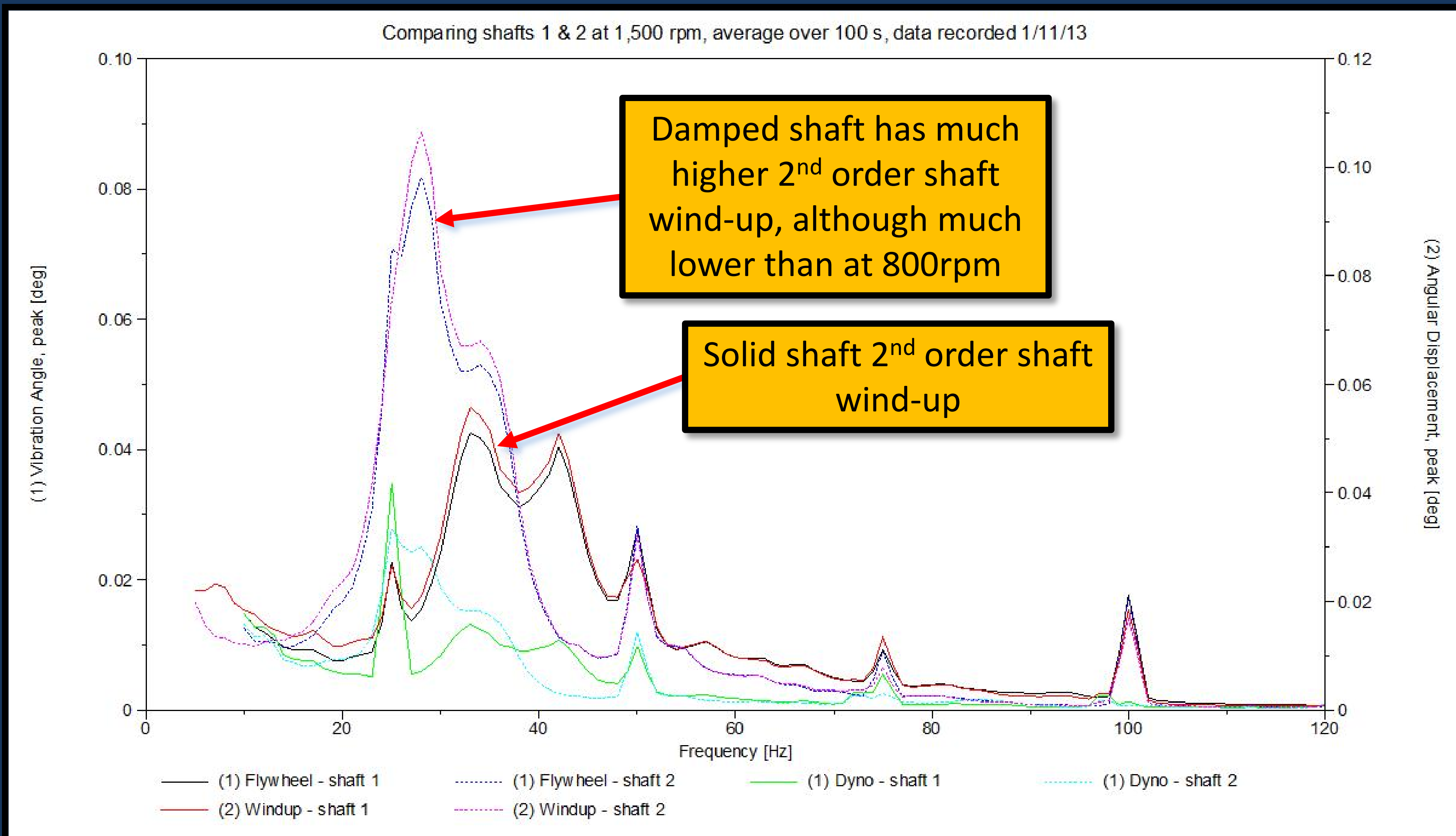
Comparison of Driveshafts at 800rpm



Damped shaft has much higher 2nd order shaft wind-up

Solid shaft 2nd order shaft wind-up

Comparison of Driveshafts at 1500rpm



Objective 2

- To quantify differences in torsional vibration dynamics in the engine test stand system between drivelines of different lengths
- Driveshaft lengths: 34.5” vs. 20.5” (long vs. short)

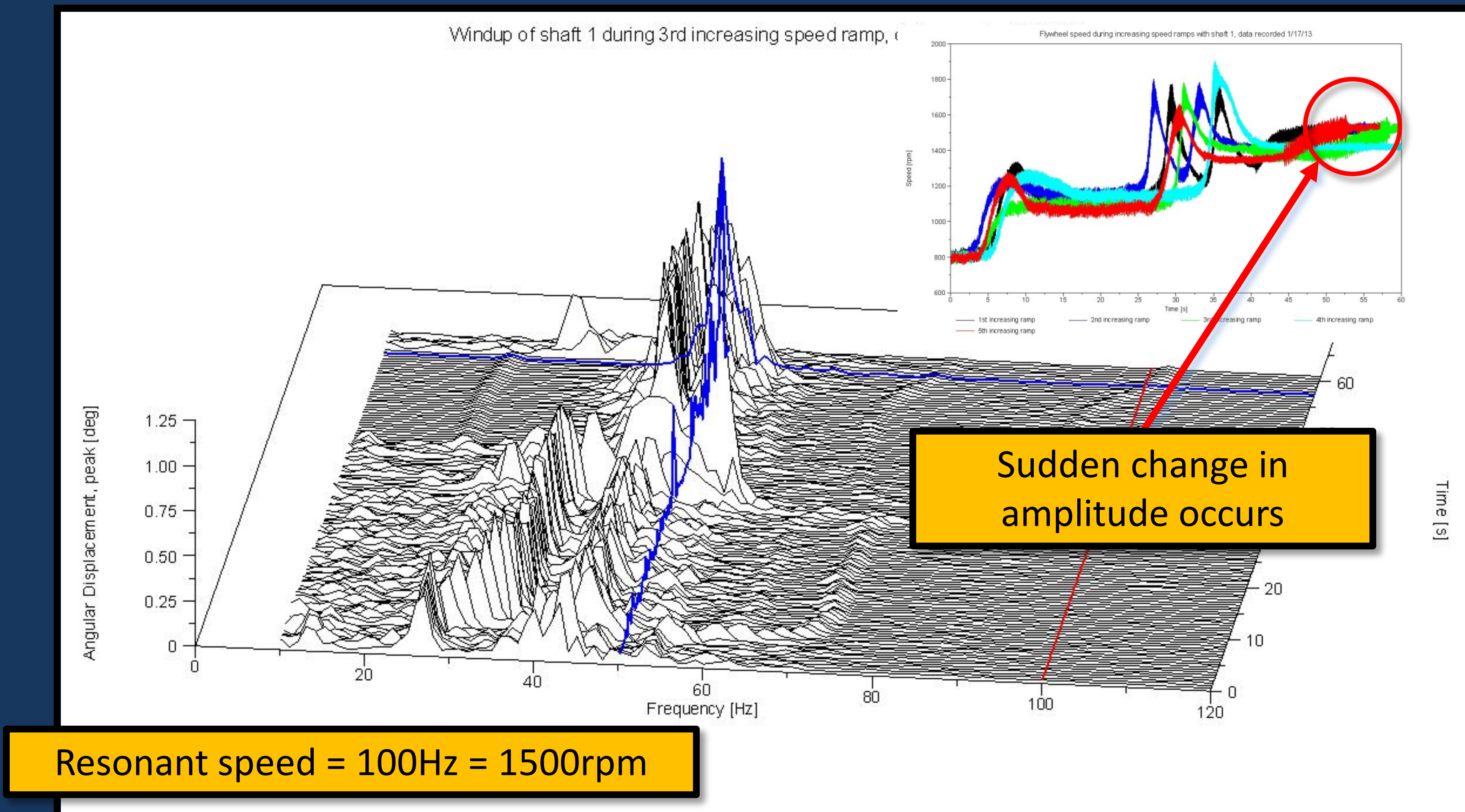
$$\omega_n = \sqrt{\frac{C}{J_{eq}}}$$

$$C = \frac{JG}{L}$$

$$J = \frac{\pi}{32}\left(D^4 - (D - 2t)^4\right)$$

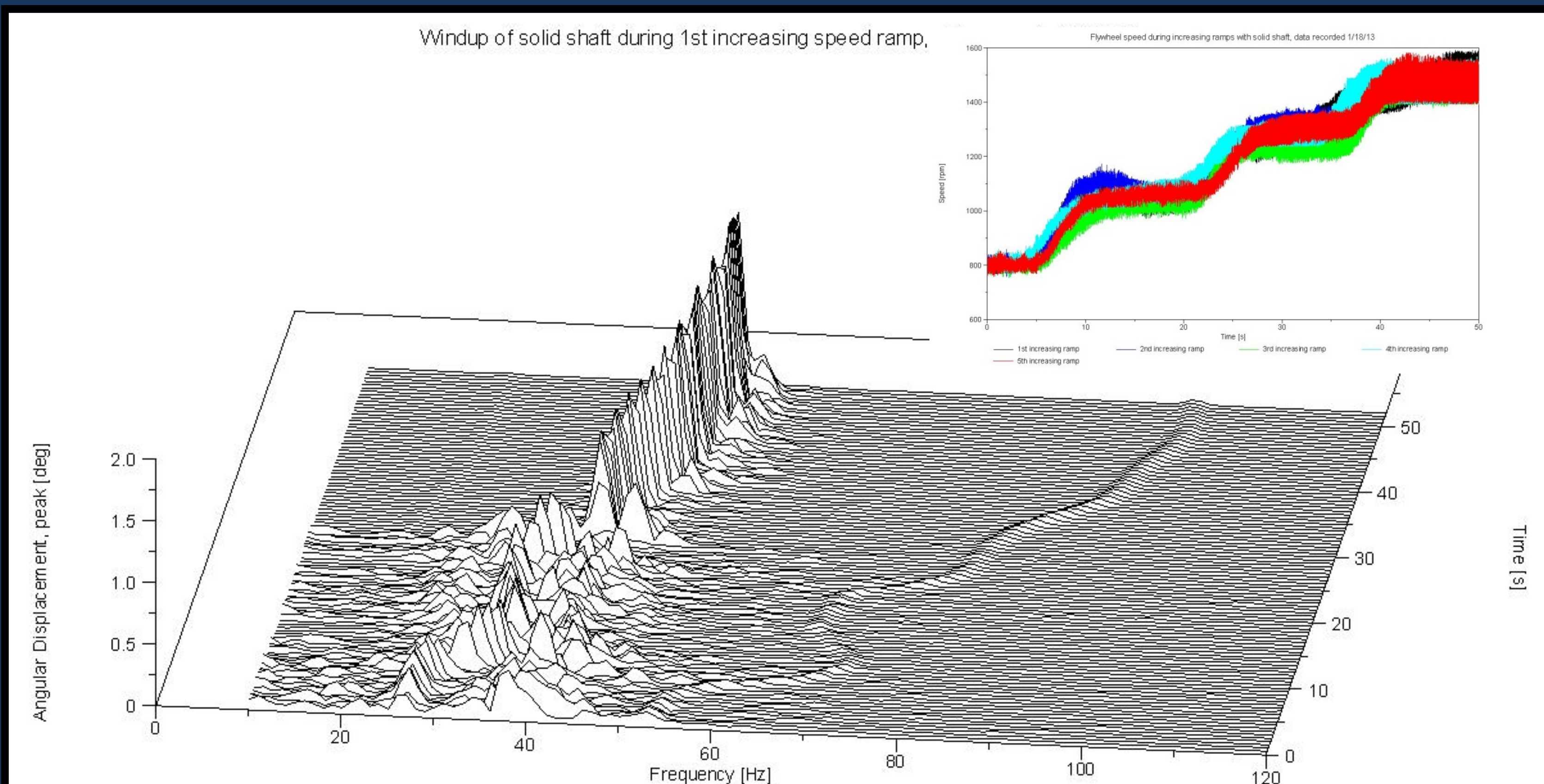
Comparison of ω_n at Different Driveshaft Lengths on Ramp

- 34.5” (Long) Solid Shaft



Comparison of ω_n at Different Driveshaft Lengths on Ramp

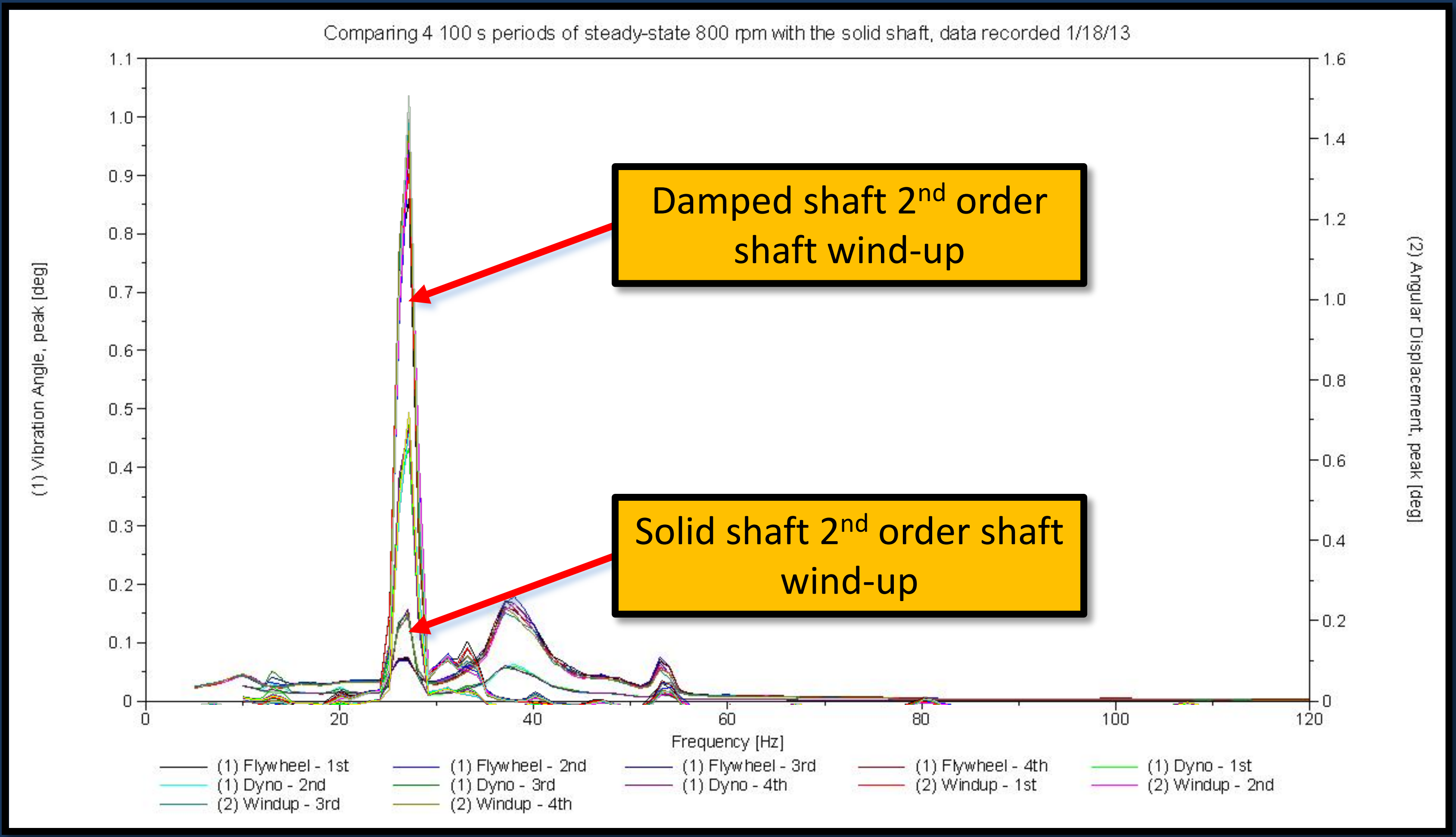
- 20.5” (Short) Solid Shaft



2nd order wind-up amplitude continues to increase after reaching 1500rpm

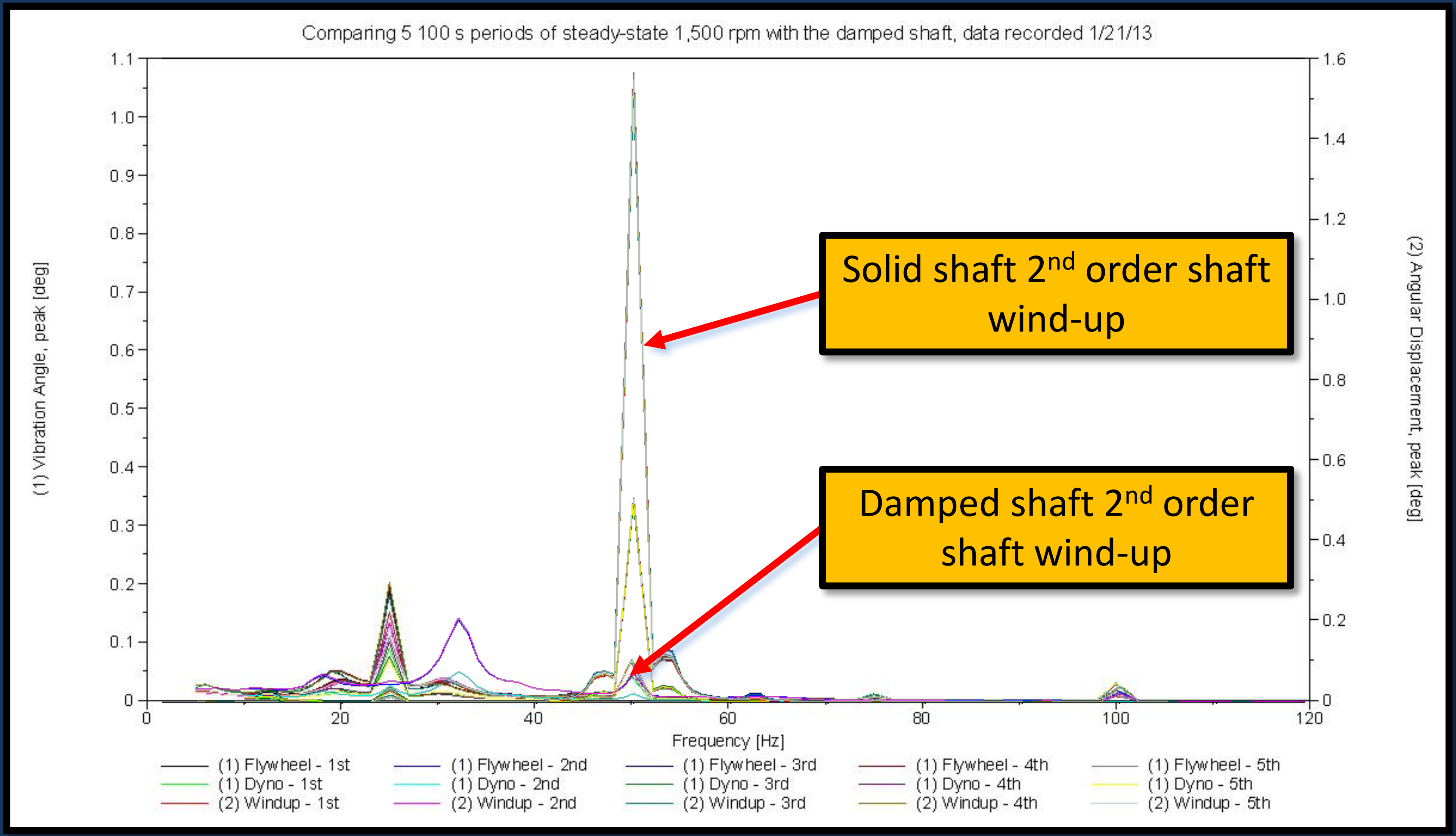
Comparison of ω_n at Different Driveshaft Lengths at 800rpm

- 20.5" Solid Shaft vs. Damped Shaft



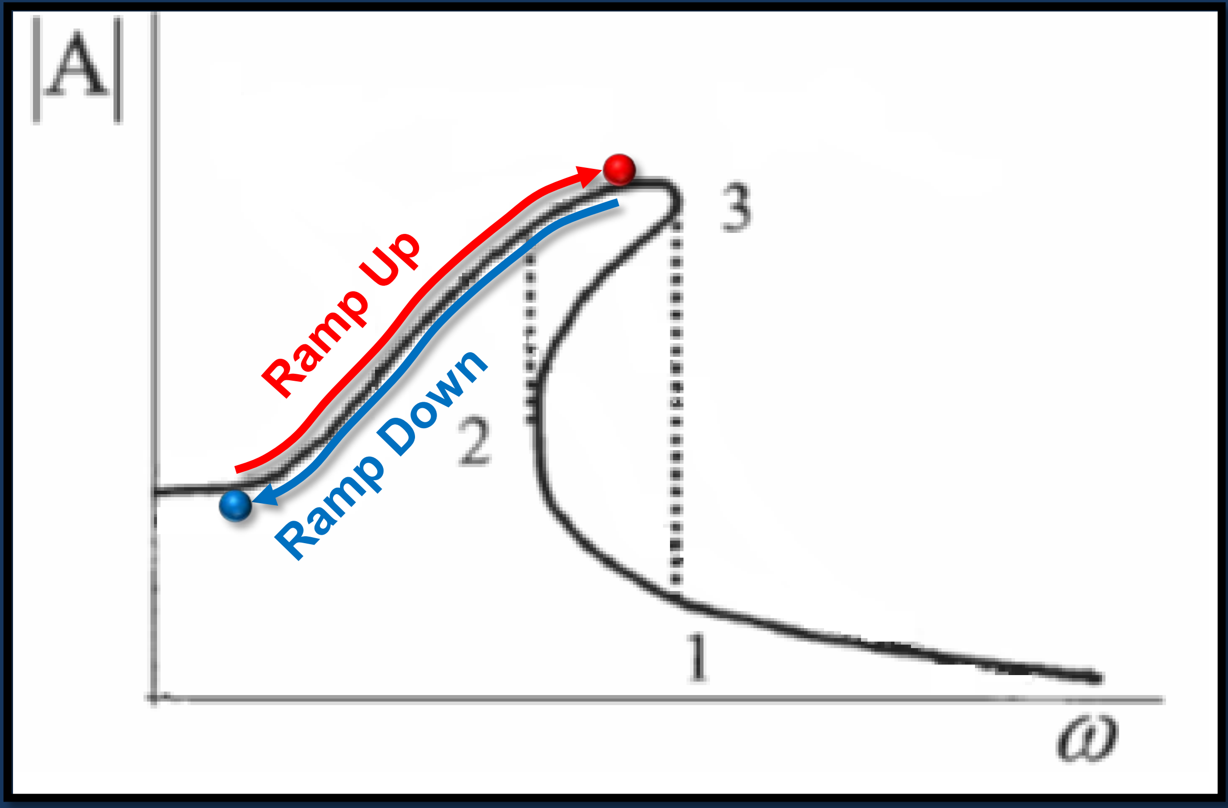
Comparison of ω_n at Different Driveshaft Lengths at 1500rpm

- 20.5" Solid Shaft vs. Damped Shaft



What is Happening with the Short Solid Shaft?

- Excitation frequency did not exceed natural frequency during ramp up (point 3)
- No Jump

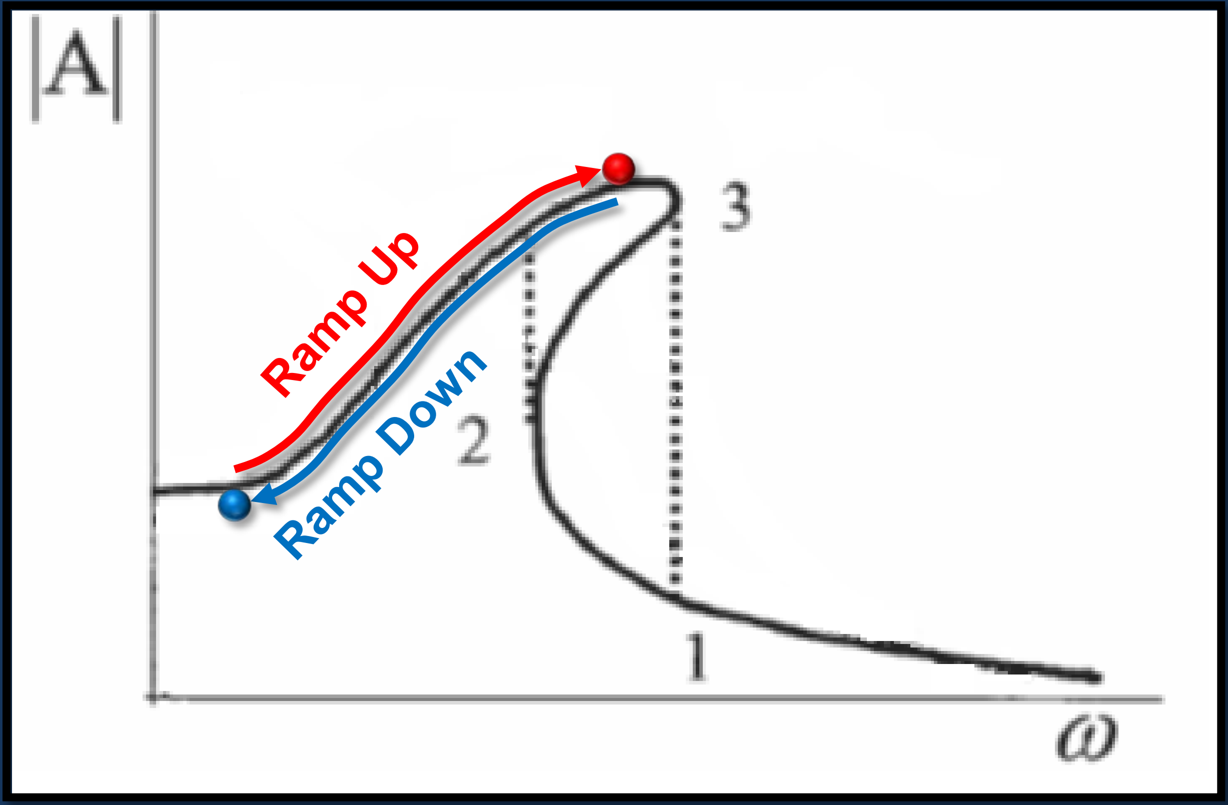


What is Happening with the Short Solid Shaft?

- Shift to higher natural frequency with shorter solid shaft

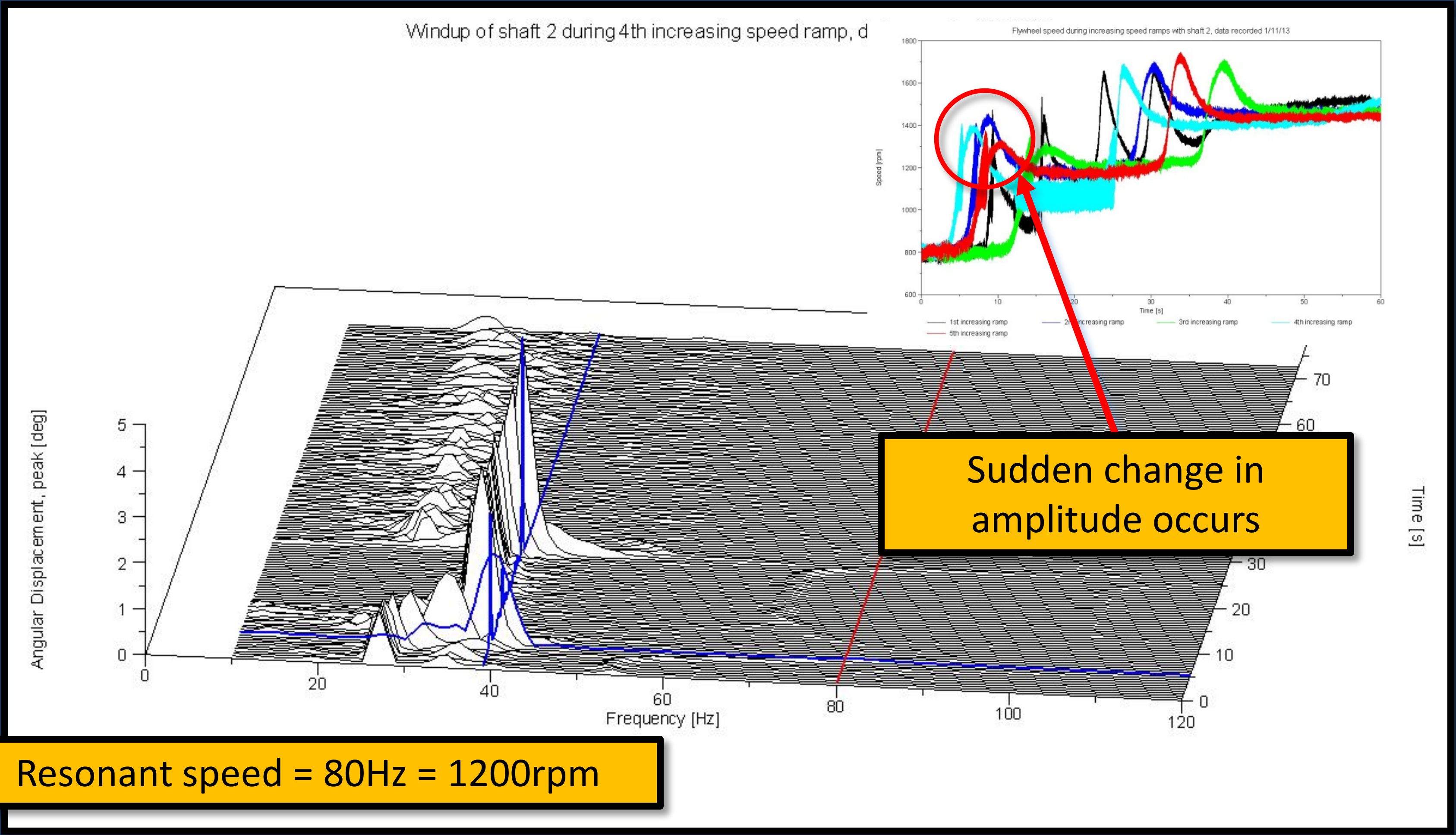
$$C = \frac{JG}{L}$$

$$\omega_n = \sqrt{\frac{C}{J_{eq}}}$$



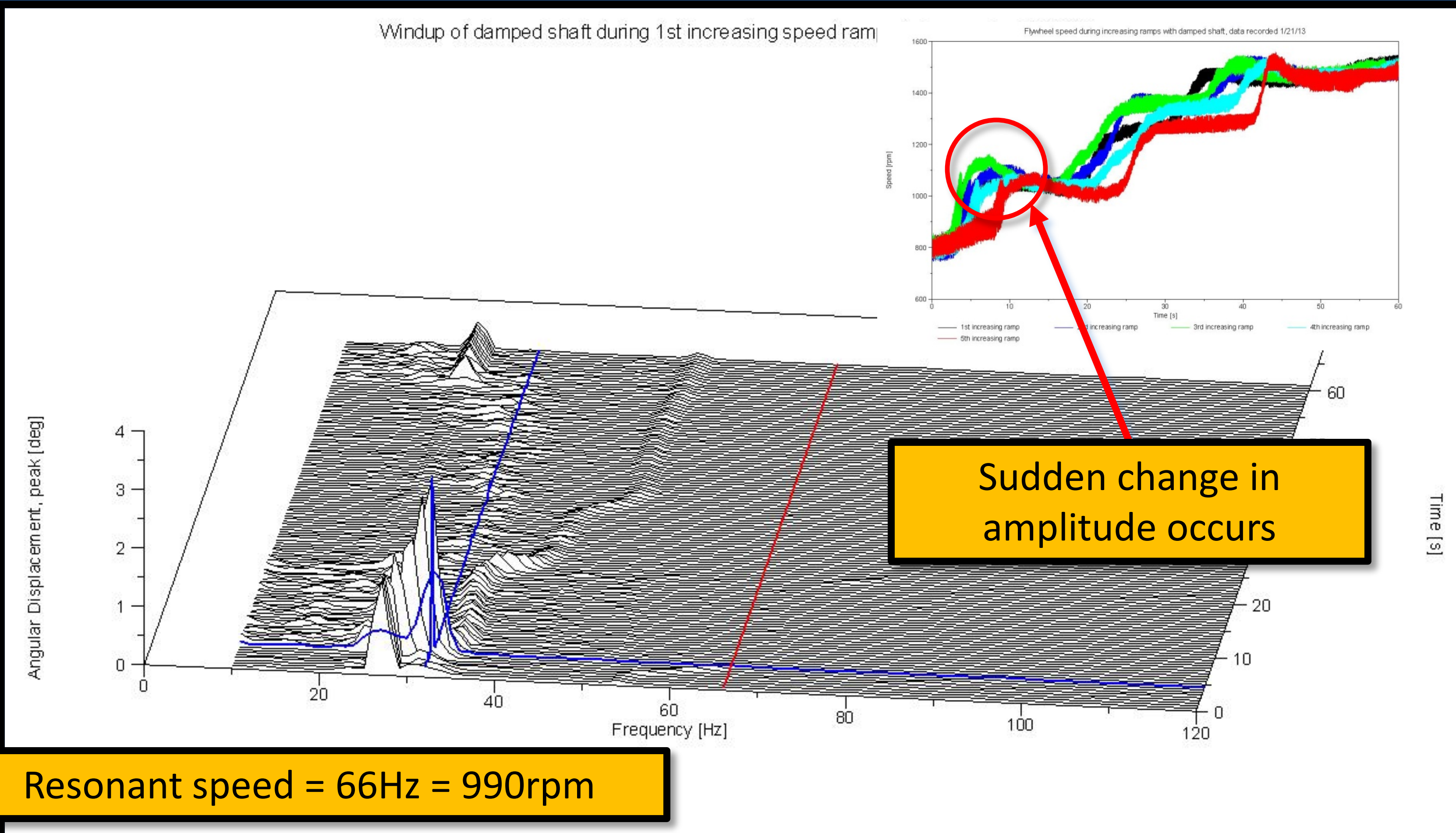
Comparison of ω_n at Different Driveshaft Lengths on Ramp

- 34.5” (Long) Damped Shaft



Comparison of ω_n at Different Driveshaft Lengths on Ramp

- 20.5” (Short) Damped Shaft



Resonant speed = 66Hz = 990rpm

Comments About Damped Driveshaft at Different Lengths

- Natural frequency shifted lower in short driveshaft
- Not expected according to stiffness equation
- Still shows driveshaft length has significant effect on vibrational response

Conclusions

- **Driveline of different *stiffness* changed the *torsional vibration dynamics* of the test stand**
  - Both driveshafts behave like hardening springs; solid shaft more so…
  - Shaft wind-up amplitudes larger with damped shaft

Conclusions

- **Driveline of different *length* also change *torsional vibration dynamics* of the test stand**
  - ***Solid Shaft:***
    - Wind-up did not reach isolation at 1500rpm with shorter shaft
    - Natural frequency shifted higher with shorter shaft
  - ***Damped Shaft:***
    - Natural frequency shifted lower with shorter shaft

Next Steps…

- Investigate potential differences between two stands with the same driveshaft
- Measure torsional vibrations at camshaft
- Measure temperature at camshaft-rocker pad contact point
- Correlate torsional vibration with contact temperature

Acknowledgments

- Dr. George Bailey – Engineering and Technical Support
- Fred Gerhart – Technical Support
- Chris Peyton – Technical Support

Questions

Thanks you for your time…

Attachment 8

Motions and Action Items
<u>As Recorded at the Meeting by Bill Buscher</u>

1) Action Item – Surveillance panel chair to solicit suppliers for a GF-5 technology reference oil with ACW performance in the 50 to 90 µm range, preferably closer to 50 µm.

2) Action Item – SP chair to inform Nissan that cylinder head components will not be necessary to include in the upcoming Nissan hardware solicitation to the ASTM labs.

3) Motion – Lab A to issue a detailed report to be included in the meeting minutes of today's meeting, on the regrinding process of Sequence IVA test camshafts, including a timeline and a dataset including camshaft lot numbers and quantities reground, by January 31, 2013. If available differentiate LTMS data within a camshaft lot by reground and non-reground camshafts.

   Dave Glaenzer / Jim Linden / Passed 12 – 0 – 1

4) Motion – Modify the Sequence IVA test procedure to allow the OHT non-nickel plated oil cooler (p/n OHTKA24-006-1), in conjunction with an OHT adapter plate (p/n OHTKA24-005-1), as an acceptable replacement for the Nissan oil cooler. The OHT oil cooler and adapter plate will be introduced at a test lab with an official calibration test, including appropriate notes in the test report comments section, on each stand. Once a lab switches from the Nissan to the OHT oil cooler on a stand, that lab will not switch that stand back to the Nissan oil cooler.

   Bill Buscher / Jerry Brys / Passed 12 – 0 – 1

5) Motion – Modify Sequence IVA test procedure to allow for 48 (from 32) runs per engine assembly and 24 (from 16) runs per cylinder head assembly. Effective 1/24/12.

   Al Lopez / Jerry Brys / Passed 12 – 0 – 1

6) Action Item – Southwest Research Institute to issue procedures for refurbishing Nissan throttle bodies, intake manifolds and exhaust manifolds.

7) Action Item – Lubrizol to issue information on suppler for remanufactured Nissan ECUs.

8) Action Item – Labs to check for supply of damaged Nissan wiring harnesses. If available, return damaged wiring harnesses to OHT for potential refurbishing.

9) Action Item – Keep RO 1006-2 targets constant at N = 25, but review and update targets at N = 30.

10) Motion – Modify section 6.4.1.3 to add a sentence to state “do not modify or alter critical test parts without surveillance panel approval”.

Rich Grundza / Jason Bowden / Passed Unanimously